U.S. DEPARTMENT OF COMMERCE
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FISH AND WILDLIFE AS RELATED TO WATER QUALITY OF THE LAKE ONTARIO BASIN

Fish and Wildlife Service
Washington, D.C.

December 1969

PB 260 071

UNITED STATES DEPARTMENT OF THE INTERIOR

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The effects of water quality upon the fish and wildlife resources of the Lake Ontario Basin are reported as part of the Great Lakes-Illinois River Basin Comprehensive Study. Lake Ontario is described with regard to morphometry, thermal conditions, light penetration and transparency, currents, chemical characteristics, plankton, and benthic organisms. Further consideration is given to fishery and wildlife base and management, economic factors, management, water quality trends, and environmental research requirements. An extensive bibliography is included.

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*Wildlife	
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UNITED STATES DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

FISH AND WILDLIFE AS RELATED TO WATER QUALITY OF THE LAKE ONTARIO BASIN

A Special Report on
Fish and Wildlife Resources

December 1969

Bd

REPORT OF THE REGIONAL DIRECTORS

Bureau of Sport Fisheries and Wildlife

Bureau of Commercial Fisheries

UNITED STATES
DEPARTMENT OF THE INTERIOR
U. S. Fish and Wildlife Service

Mr. H. W. Poston, Regional Director
Federal Water Pollution Control Administration
U. S. Department of the Interior
33 East Congress Parkway, Room 410
Chicago, Illinois 60607

Dear Mr. Poston:

This is a report on the effects of water quality upon the fish and wildlife resources of the Lake Ontario Basin. It has been prepared under the authority and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and is in response to your request for our participation in the Great Lakes-Illinois River Basin Comprehensive Study.

This letter summarizes briefly the findings of the U. S. Fish and Wildlife Service in cooperation with the New York Conservation Department. It is supported in detail by information included in the attached substantiating report.

Fish and wildlife resources and their habitats have been affected significantly in various areas by changes in water quality in the Lake Ontario Basin. The attached report describes these resources and habitats, the relationship of water quality to them, and discusses their role with respect to programs of water quality betterment.

Lake Ontario is the smallest of the Great Lakes, with 7,520 square miles of water area and 34,800 square miles of drainage area. Its average depth of 283 feet is second only to Lake Superior's depth of 487 feet. Maximum depth of Lake Ontario is 804 feet. All of Lake Ontario's United States shoreline borders the State of New York.

Fishery Resources

The present sport fishery of Lake Ontario and other basin waters constitutes only a small portion of the potential. There are several hundred thousand acres of fishable waters in the lake proper, plus many thousands more in basin lakes and streams. A wide variety of fish species, both warm water and cold water, exist in these areas. The 1960 fishing pressure for the Lake Ontario Basin is estimated at 3.2 million angler days. This use is expected to double by the year 2020.

Historically, Lake Ontario has been the lowest producer of commercial fish products of all the Great Lakes. Since the turn of the century, when the annual catch was about 5.5 million pounds, the commercial take has gradually declined to a low of 1.8 million pounds in 1966. The United States portion of the catch from Lake Ontario makes up a small portion of the total catch. The projected demand to 2020 for Great Lakes fish is expected to increase four-fold from the past annual 100 million pound production of the five lakes. Demands on the Lake Ontario commercial fishery are expected to parallel the overall Great Lakes pattern. While many tributaries of Lake Ontario are not fished commercially, they do supply spawning areas for important commercial and sport fish.

Species composition and commercial production remained relatively stable prior to the 1930's, but since then they have undergone major changes. Stocks of lake trout, whitefish, blue pike and sturgeon, have been eliminated or drastically reduced. Carp, white perch, smelt, and probably alewives, have increased. Walleye, yellow perch and catfish have undergone less obvious changes. The alewife is now the dominant species. Causes of these changes are not fully understood, but contributing factors include environmental deterioration in some areas, selective over-fishing of some species, and lamprey predations on depleted desirable species. With the loss of high value species, there has been a shift in the commercial fishery to greater emphasis on carp, white perch, eels and yellow perch. The number of full-time fishermen has declined sharply.

The experimental introduction of kokanee, coho and chinook salmon and splake trout by Ontario and/or New York may provide substantial fishing in the near future.

Research programs are needed to better establish cause and effect relationships and to better document problem sources. Careful monitoring of the fishery base will be necessary as research activities proceed, in order to detect the nature and extent of changes that occur and to indicate needed adjustments in management procedures. A mutually supportive relationship between the sport and commercial fisheries is essential, since balanced utilization of the total fishery resource is a major goal.

Wildlife Resources

The Lake Ontario Basin supports an abundant and varied wildlife fauna. The portion of the watershed in the Adirondack Mountain Region is famous for its "wilderness" habitat. White-tailed deer and ruffed grouse are plentiful. Other areas of the basin, such as the marshes of the Montezuma National Wildlife Refuge, are heavily used by ducks, geese and other waterfowl. These marshes are also well known for their production of muskrats and other fur animals.

The 1960 hunting pressure in the Lake Ontario Basin is estimated at approximately 1.8 million hunter days. Estimates of annual hunter use by the year 2020 approaches 4.6 million hunter days.

Fish and Wildlife Aspects of Water Quality Planning

A large share of the economic and recreational values of the Lake Ontario Basin depends directly upon the lake, its bays, and inshore waters. Fish and wildlife depend vitally upon high quality water, which meets the various biological requirements for feeding, growth, reproduction, and survival.

Except for a few inshore areas near the mouths of the larger tributaries, Lake Ontario waters are of relatively high quality. However, there have been some indications of change. Filamentous algal blooms have increased greatly in recent years in the eastern basin and in some inshore areas, creating commercial and sport fishing problems. In the open lake, there has been a steady increase in total dissolved solids since 1900. This timing has paralleled the increase in Lake Erie, but the great depth of Lake Ontario has prevented serious oxygen depletion problems. Oil wastes from commercial vessels, as well as from onshore storage tanks, present a threat to waterfowl and to the entire aquatic community. The importance of exercising strict control over pollutants entering Lake Ontario from sources within the basin must be stressed. However, the overriding determinant of Lake Ontario water quality will continue to be the quality of waters received from Lake Erie. Lake Ontario remains in relatively unspoiled condition. We have a public trust to keep it that way. Further contamination from the outside, including Lake Erie, will make the job increasingly difficult.

As a result of the 1965 Water Quality Act, New York has developed water quality standards to protect the fish and wildlife resources of Lake Ontario. These standards, when fully implemented and enforced, will do much to insure continued supplies of high quality fish and wildlife resources in the Lake Ontario Basin.

Much remains to be learned about the specialized needs of aquatic life. Additional research may demonstrate the need for re-definition and refinement of the standards to meet fish and wildlife requirements. In the meantime, existing water quality over most of Lake Ontario exceeds standards for most, if not all, parameters. Until careful research demonstrates beyond a reasonable doubt that degradation of existing water quality to the level of the standards will not result in harmful effects upon fish and aquatic life resources, it is the position of the Fish and Wildlife Service that the goal of pollution abatement in Lake Ontario should be retention of the existing overall high quality of its waters. This

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will require improving conditions in certain local areas such as the Niagara, Oswego, Genesee, and Black Rivers which are significant sources of pollution. Maintaining Lake Ontario's purity will also depend heavily on the success of present and future efforts to halt the acceleration of enrichment and other pollution of Lake Erie. Programs to maintain the present water quality in the open waters of Lake Ontario are meaningless unless the water flow from Lake Erie is prevented from further deterioration.

Because of their inherent sensitivity to subtle, long-range environmental changes, fish and aquatic organisms furnish excellent biological indicators of such changes. This enables problems to be recognized and corrective action taken before the problems become critical. This has not been recognized sufficiently in the past. A change of emphasis is called for in the future, including acceleration of necessary research and monitoring in the fish and wildlife aquatic organism sector of water quality. This is particularly important in areas proposed as fossil or nuclear thermal discharge sites.

To obtain maximum benefits from an environmental research program and to assure continuity in data collection, there must be adequate coordination and exchange of information. Fishery agencies have a broad responsibility to maintain harvestable surpluses in existing populations of aquatic life and to contribute to man's understanding and control of aquatic living resources and their environment. It also seems logical that these agencies should play a major role in coordinating and conducting research related to long-term water quality changes. Without proposing any specific institutional arrangements, this function might best be exercised through such established mechanisms as the Great Lakes Fishery Commission, where an ecosystem approach encompassing all of the Great Lakes can be adopted.

Recommendations

On the basis of the foregoing considerations, it is recommended that:

1. The Federal Water Pollution Control Administration's water pollution control plan for the Lake Ontario Basin be implemented as a first step, while recognizing that it may not be sufficient in its present form to solve all fish and wildlife-related water quality problems.

2. Where the existing water quality of Lake Ontario is higher than the approved standards, no degradation be permitted until careful research demonstrates beyond a reasonable doubt that such action will not result in harmful effects upon fish and wildlife resources.

3. Research programs be expanded to develop improved methods of treating wastes in major problem areas, with sufficient coordination maintained with fish and wildlife interests to insure proper consideration of fish and wildlife needs.

4. Local, State, and Federal pollution laws and enforcement programs be reviewed and revised periodically, in accordance with improved techniques and changing fish and wildlife water quality standards.

5. A permanent water quality monitoring system be established which recognizes fish and wildlife needs and which will include all areas of recognized importance to fish and wildlife. It is further recommended that Federal Water Pollution Control Administration administer this program, with appropriate assistance from fish and wildlife conservation agencies.

6. Pre-operational and post-operational studies be implemented at all proposed thermal discharge sites.

7. Increased emphasis be placed on research and operations aimed toward control of agricultural pollution, including such sources as pesticides, herbicides, fertilizers, siltation, and streambank erosion.

8. Because of the special relationship between fish, wildlife, and aquatic organisms and long-term changes in water quality and because of the responsibility of fishery agencies to better manage aquatic living resources and their environment, research on long-range environmental changes be conducted by appropriate agencies concerned with all major water uses and coordinated through established institutions with the help and cooperation of private and educational groups.

The above recommendations are intended to conserve and develop existing resources. We recognize that implementation of these recommendations will require the strong support and active cooperation of numerous Federal and State agencies. In addition to your agency, these include the New York Conservation Department as well as local agencies, private industry, and the citizenry in general. The services of the Fish and Wildlife Service remain available to assist in this important effort in any way possible.

Sincerely yours,

R. W. Burwell, Regional Director
Bureau of Sport Fisheries and Wildlife

W. F. Carbine

W. F. Carbine, Regional Director
Bureau of Commercial Fisheries

SUBSTANTIATING REPORT

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PREFACE

This study is authorized under the Federal Water Pollution Control Act, Section 3(a) PL 660, as amended, and in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

Interest in, and authority for participation by fisheries interests in such studies originate in a Congressional Act of March 3, 1887 (16 U.S.C. 744) which authorized the Commissioner, United States Fish Commission, to prosecute investigations and inquiries concerning the supply of food fishes of the coasts and lakes of the United States and the determination of protective, prohibitory or precautionary measures to be adopted. Subsequent legislation, particularly the Fish and Wildlife Act of 1956, as amended, and the Fish and Wildlife Coordination Act of 1958, as amended, refined and strengthened these responsibilities. Section 5 of the Fish and Wildlife Coordination Act authorizes the Secretary of the Interior, through the Bureaus of Sport Fisheries and Wildlife and Commercial Fisheries, and the Bureau of Mines, to make such investigations as he deems necessary to determine the effects of domestic sewage, mine, petroleum and industrial wastes, erosion silt, and other polluting substances on wildlife. The Act also authorizes reports to Congress concerning such investigations and offers recommendations for alleviating dangerous and undesirable effects of such pollution. These investigations shall include (1) the determination of standards of water quality for the maintenance of wildlife; (2) the study of methods of abating and preventing pollution, including methods for the recovery of useful or marketable products and by-products of wastes; and (3) the collation and distribution of data on the progress and results of such investigations for the use of Federal, State, municipal and private agencies, individuals, organizations or enterprises.

In keeping with these authorities, this report has been prepared by the Bureau of Commercial Fisheries and the Bureau of Sport Fisheries and Wildlife as a Fish and Wildlife Service report for the Lake Ontario Basin portion of the Federal Water Pollution Control Administration study.

The analyses in this report are based on statistical records, field investigations, published material, and the experience and judgment of a staff that has worked with the resource for many years. While far from complete for a resource base as large and complex as the Lake Ontario Basin, this background is considered sufficient for indicating the dimensions of the resource and for making reasoned judgments on trends, problems, and future requirements. A list of references is attached to facilitate more detailed inquiry and, where appropriate, the text has been annotated selectively.

ACKNOWLEDGMENTS

The published studies and surveys used in preparing this report are credited in the list of references. In addition, the encouragement, interest, basic data, ideas, and assistance contributed by the following agencies have helped greatly in preparing this report:

Federal Agencies

Bureau of Outdoor Recreation
Corps of Engineers
Federal Water Pollution Control Administration
Geological Survey
Public Health Service

Foreign Agency

Ontario Department of Lands and Forests

International Agency

Great Lakes Fishery Commission

State Agency

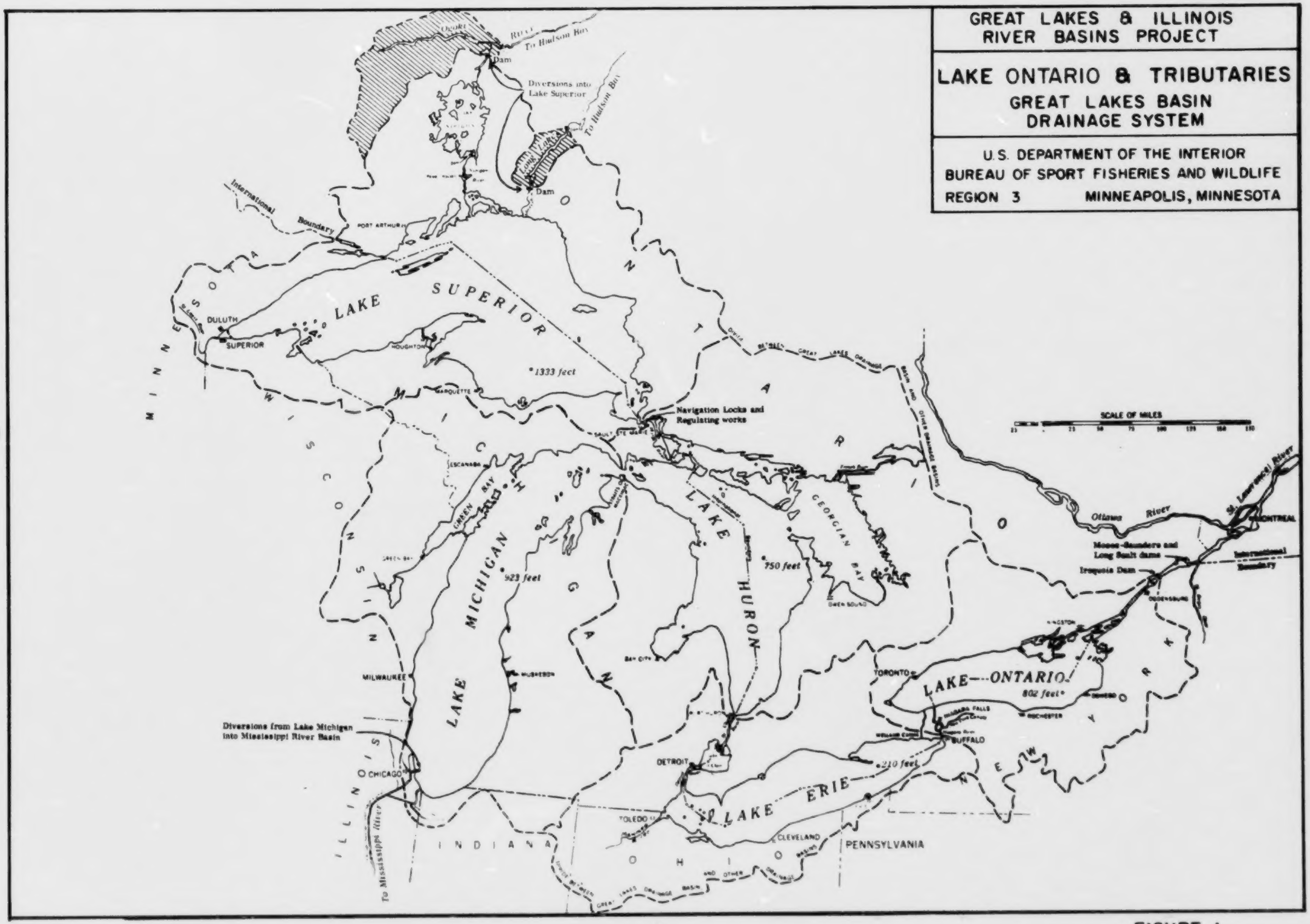
New York Conservation Department

INTRODUCTION

The five Great Lakes and their connecting waters have a combined surface area of over 95 thousand square miles. They form the largest group of lakes in the world. The geographical area covered by this study, however, comprises only the United States portion of the Great Lakes and their watersheds, plus the Illinois River and its drainage basin.

The latter basin adds 30,000 more square miles. Figures 1 and 2 and Table 1 present pertinent physical data on the Great Lakes system.

The abundant supply of fish in the Great Lakes played an important part in the development of the bordering land areas from the beginning of human settlements. Until about 1830, commercial fishing was confined almost exclusively to the Indians and employees of the Hudson Bay and American and Northwest Fur Companies. With the development of more efficient harvesting gear and better transportation, commercial fishing in the Great Lakes began to expand. While never of first rank in terms of the total economy of the area, the fisheries of the Great Lakes have made, and still make, a significant contribution. In numerous local areas, this economic contribution has been a major one. Table 2 summarizes total Great Lakes commercial fishery landings and values during recent decades.



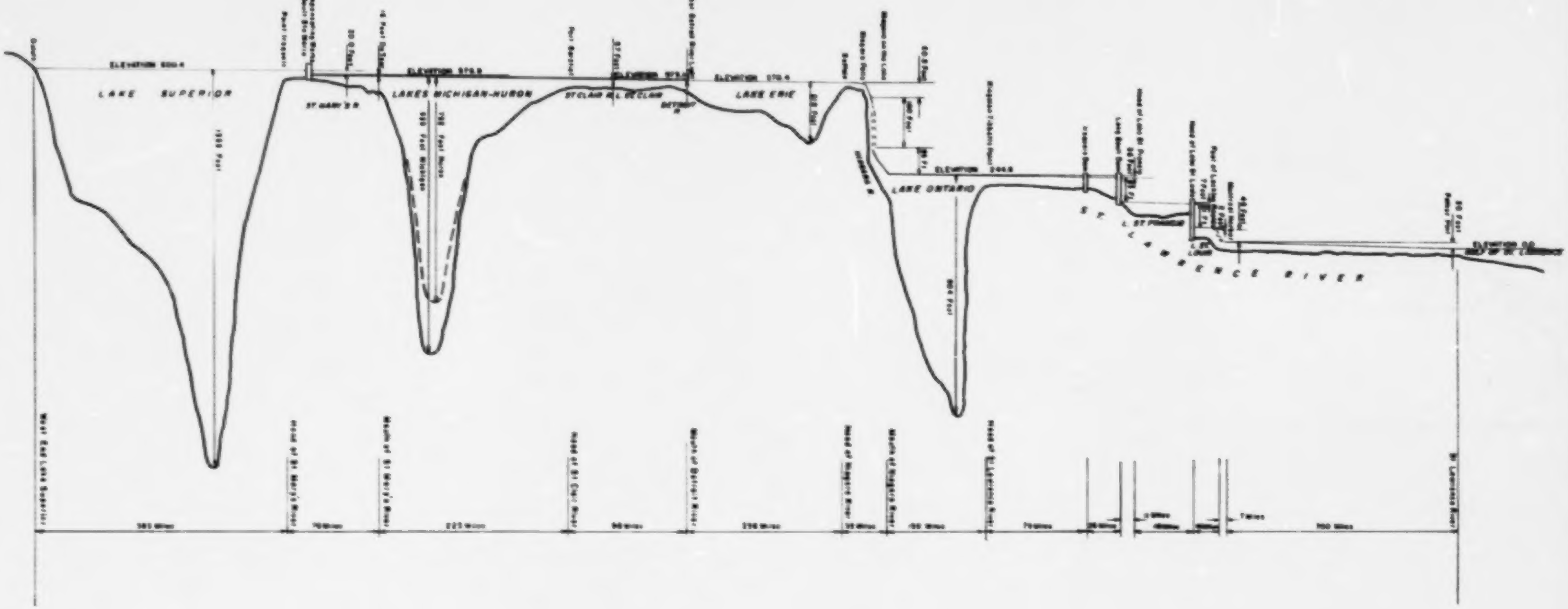
GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE ONTARIO & TRIBUTARIES
GREAT LAKES BASIN
DRAINAGE SYSTEM

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

Ogoki River
To Hudson Bay
Dam
Diversions into Lake Superior
To Hudson Bay
Long Lake
Dam
International Boundary
PORT ARTHUR
MINNESOTA
ONTARIO
DULUTH
SUPERIOR
LAKE SUPERIOR
HOUGHTON
1333 feet
MARQUETTE
Navigation Locks and Regulating works
SAULT STE MARIE
DIVIDE BETWEEN GREAT LAKES DRAINAGE BASIN AND OTHER DRAINAGE BASINS
SCALE OF MILES
25
25
50
75
100
125
150
WISCONSIN
MICHIGAN
ESCANABA
GREEN BAY
LAKE MICHIGAN
923 feet
LAKE HURON
750 feet
GEORGIAN BAY
OWEN SOUND
Ottawa River
St. Lawrence River
MONTREAL
Moses-Saunders and Long Sault dams
International Boundary
Iroquois Dam
OGDENSBURG
KINGSTON
BAY CITY
MUSKEGON
MILWAUKEE
Diversions from Lake Michigan into Mississippi River Basin
CHICAGO
TORONTO
LAKE ONTARIO
802 feet
OSWEGO
NIAGARA FALLS
ROCHESTER
WELLAND CANAL
BUFFALO
NEW YORK
DETROIT
210 feet
LAKE ERIE
TOLEDO
CLEVELAND
PENNSYLVANIA
ILLINOIS
INDIANA
OHIO
To Mississippi River
DIVIDE BETWEEN GREAT LAKES DRAINAGE BASIN AND OTHER DRAINAGE BASINS

FIGURE 1



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE ONTARIO & TRIBUTARIES
GREAT LAKES
ST. LAWRENCE RIVER PROFILE

U. S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

E.M.P. 690313

FIGURE 2

Table 1. Physical Data of Great Lakes System[1]

Lake	Length (Mile)	Breadth (Mile)	Water area (sq. miles) U.S.	Water area (sq. miles) Canada	Total	Average surface elevation since 1860 (feet)	Maximum Depth (feet)	Mean Depth (feet)	Drainage area (sq. mile)
Superior	350	160	20,700	11,120	31,820	602.20	1,333	487	80,000
Michigan	307	118	22,400	-	22,400	580.54	923	276	67,860
Huron	206	183	9,110	13,900	23,010	580.54	750	195	72,620
St. Clair	26	24	200	290	490	574.88	21	10	7,430
Erie	241	57	4,990	4,940	9,930	572.34	210	58	32,490
Ontario	193	53	3,600	3,920	7,520	246.03	802	283	34,800
Totals:			61,000	34,170	95,170				295,200

---

[1] Adapted from Beeton and Chandler "St. Lawrence Great Lakes" LIMNOLOGY IN NORTH AMERICA - University of Wisconsin Press - 1964.

Table 2. Average Commercial Landings and Value of Fish From the Great Lakes, Including Both the United States and Canada

Years	Landings (Millions of Pounds)	Value (Millions of Dollars)*
1920-1929	106.2	8.8
1930-1939	111.7	7.6
1940-1949	101.1	14.9
1950-1959	111.3	15.6
1960	104.5	10.8
1961	113.4	11.4
1962	116.4	9.5
1963	99.6	9.3
1964	88.6	9.5
1965	96.8	10.8
1966	115.6	10.3

* Dollar values uncorrected for general price level increases caused by inflation.

In recent years, the commercial fishing industry has been beset with many problems, among them being drastic declines of the choicer species. After a sharp increase in the value of the catch in the decade 1940-1949, a leveling-off took place during the 1950's, with severe drops in the early 1960's, followed by some recovery in the mid-portion of the decade (Table 2). Total production (United States and Canada combined) has remained essentially stable, in the neighborhood of 100-million pounds annually.

Fishing and hunting are popular activities on the many miles of streams, lakes and wildlife areas available in the basin.

Problems encountered in sport fishing and hunting are primarily due to man's activities. Some areas have to be lost to "progress", but curbing the unnecessary destruction of habitat of food sources is needed to insure a continued supply of fish and game for the future.

DESCRIPTION OF THE BASIN

GENERAL

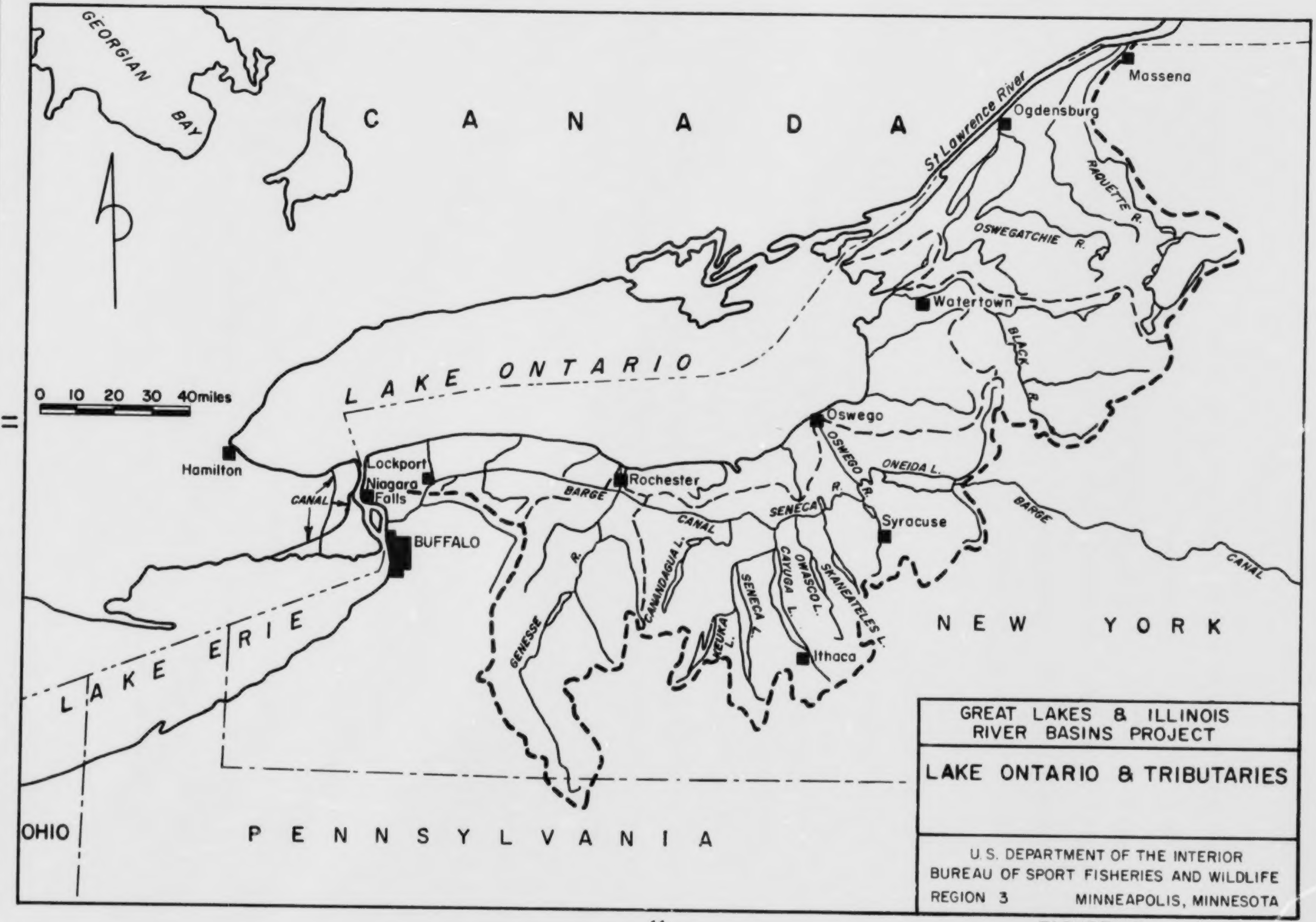
Consideration of habitat (environmental) factors is essential for adequate understanding of fishery dynamics and potential. Water quality factors (the chief interest of this study) are closely related to such consideration. Knowledge of the habitat base of the Lake Ontario Basin is far from complete. The following section will attempt to summarize available information. The summary will consider both Lake Ontario and its tributary streams and lakes.

The Lake Ontario study area (Figure 3) includes the U. S. portion of the lake, its watershed, and the U. S. portion of the St. Lawrence River to the International Boundary Line, at Massena, New York. In order to coordinate this study with those of cooperating agencies, the study area was subdivided into several subbasins in addition to the lake proper. The subbasins include: Niagara River Basin, Genesee River Basin, Oswego River Basin, Black River Basin and St. Lawrence River Basin.

The 1960 human population of the Lake Ontario Basin was 2.1 million. The projected human population for the year 2020 is approximately 4.3 million.

LAKE ONTARIO

Morphometry.--Lake Ontario, although the smallest of the Great Lakes ranks 14th in size among the lakes of the world. It receives 85


GEORGIAN BAY
C A N A D A
St Lawrence River
Massena
Ogdensburg
RAQUETTE R.
OSWEGATCHIE R.
Watertown
BLACK R.
LAKE ONTARIO
0 10 20 30 40miles
Hamilton
Lockport
Niagara Falls
CANAL
BUFFALO
Rochester
BARGE
CANAL
Oswego
OSWEGO R.
ONEIDA L.
SENECA R.
Syracuse
BARGE
CANAL
GENESSE R.
CANANDAGUA L.
KEUKA L.
SENECA L.
CAYUGA L.
OWASCO L.
SKANEATELES L.
Ithaca
NEW YORK
LAKE ERIE
OHIO
PENNSYLVANIA

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE ONTARIO & TRIBUTARIES

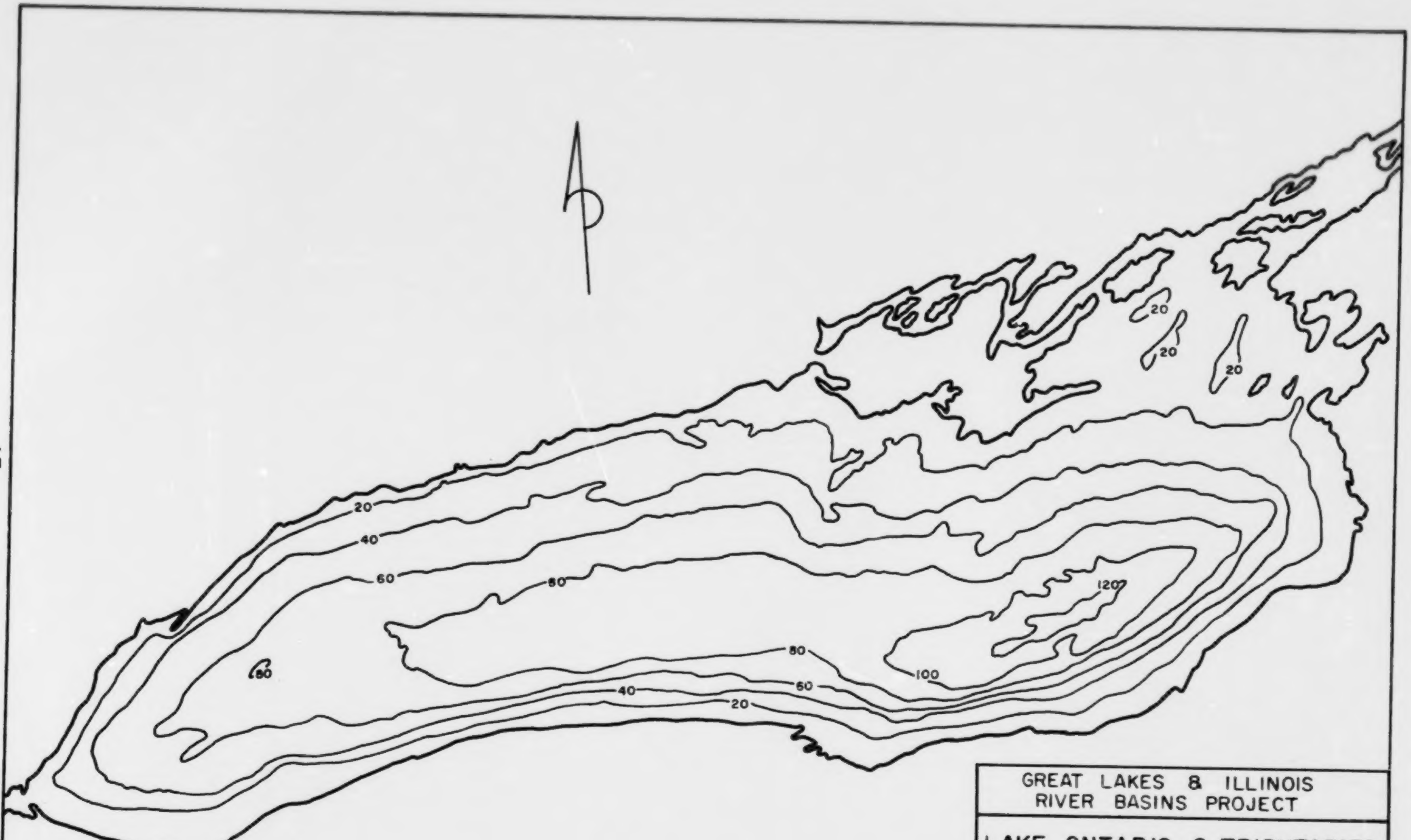
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 3

percent of its water from Lake Erie via the Niagara River (Figure 3). The St. Lawrence River carries the discharge of Lake Ontario 502 miles to the Atlantic Ocean. The difference in mean surface level between Lakes Erie and Ontario is approximately 326 feet (Figure 2). Inflow through the Niagara River varies between 117,000 and 254,000 c.f.s. with a mean discharge of 205,000 c.f.s. Mean outflow from Lake Ontario is 240,000 c.f.s. The lake is 193 miles long with a maximum width of 53 miles. The U. S. portion of the drainage basin is 17,700 square miles plus 3,600 square miles of water surface.[1]

One of the most important morphological features of Lake Ontario is its depth. The maximum depth of 804 feet is greater than that of Lake Erie or Lake Huron. Its average depth of 283 feet is exceeded by only Lake Superior.[2] Depths less than 20 fathoms occur only very near shore and in the northeast portion of the lake, near the St. Lawrence River (Figure 4). Lake Ontario has a greater percentage of its area deeper than 20 fathoms than other Great Lakes, with the exception of Lake Superior (Figures 5 and 6). The volume of Lake Ontario (Figure 7) follows a curve similar to the depth-area curve (Figure 6). The deepest portion of the lake is in the southeast. A number of islands and the extensive Bay of Quinte are found in the relatively shallow northeast.[1]

Thermal Conditions.--The waters of Lake Ontario undergo considerable thermal change seasonally. By June, the surface water near shore is 10-14°C. (50°57°F.) and the epilimnion is about 10 meters thick. The epilimnion becomes warmer as the summer progresses, although


20
40
60
80
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40
20
100
120
80
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20

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE ONTARIO & TRIBUTARIES
DEPTH CONTOURS (FATHOMS)

U.S. DEPARTMENT OF THE INTERIOR
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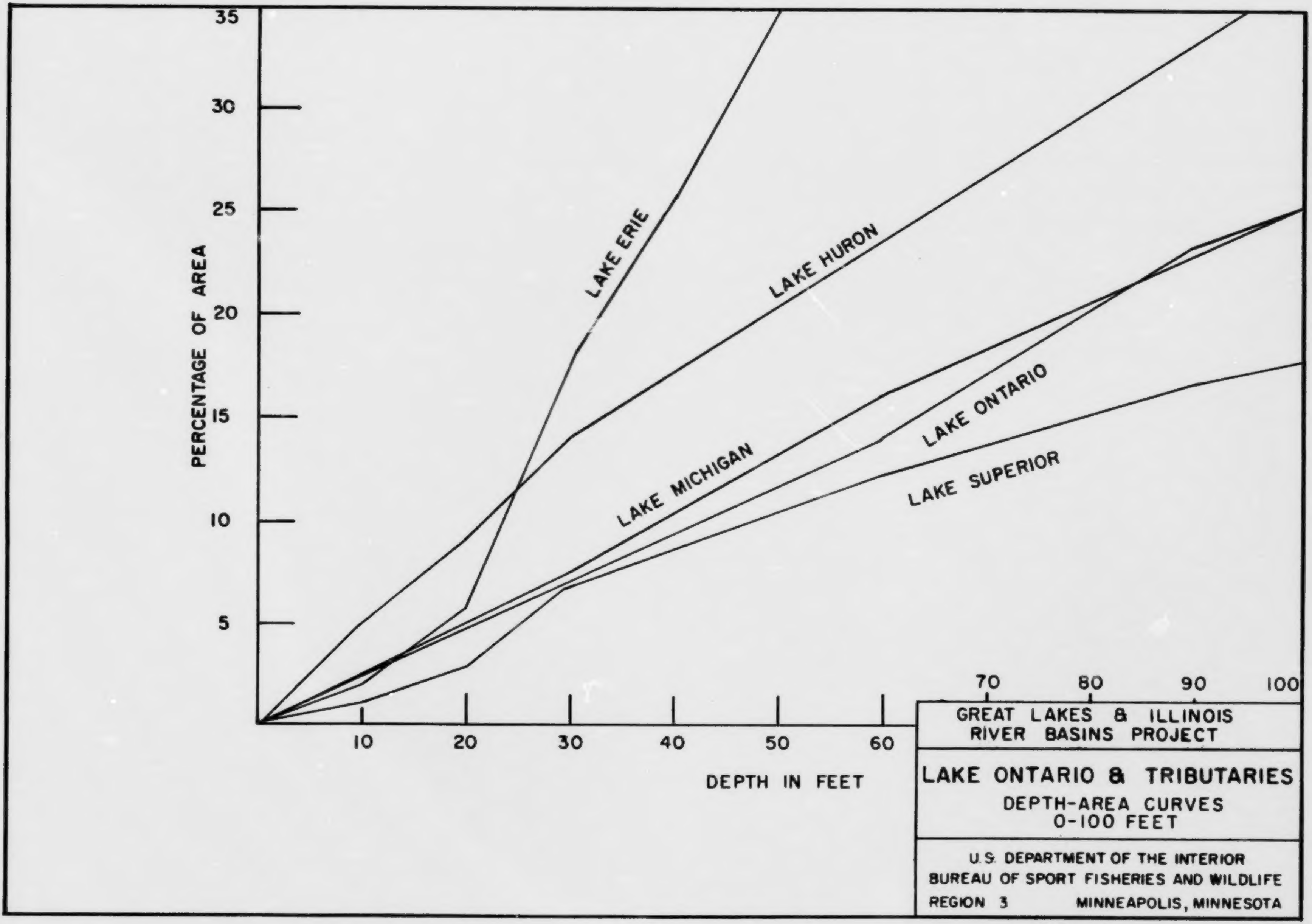
FIGURE 4

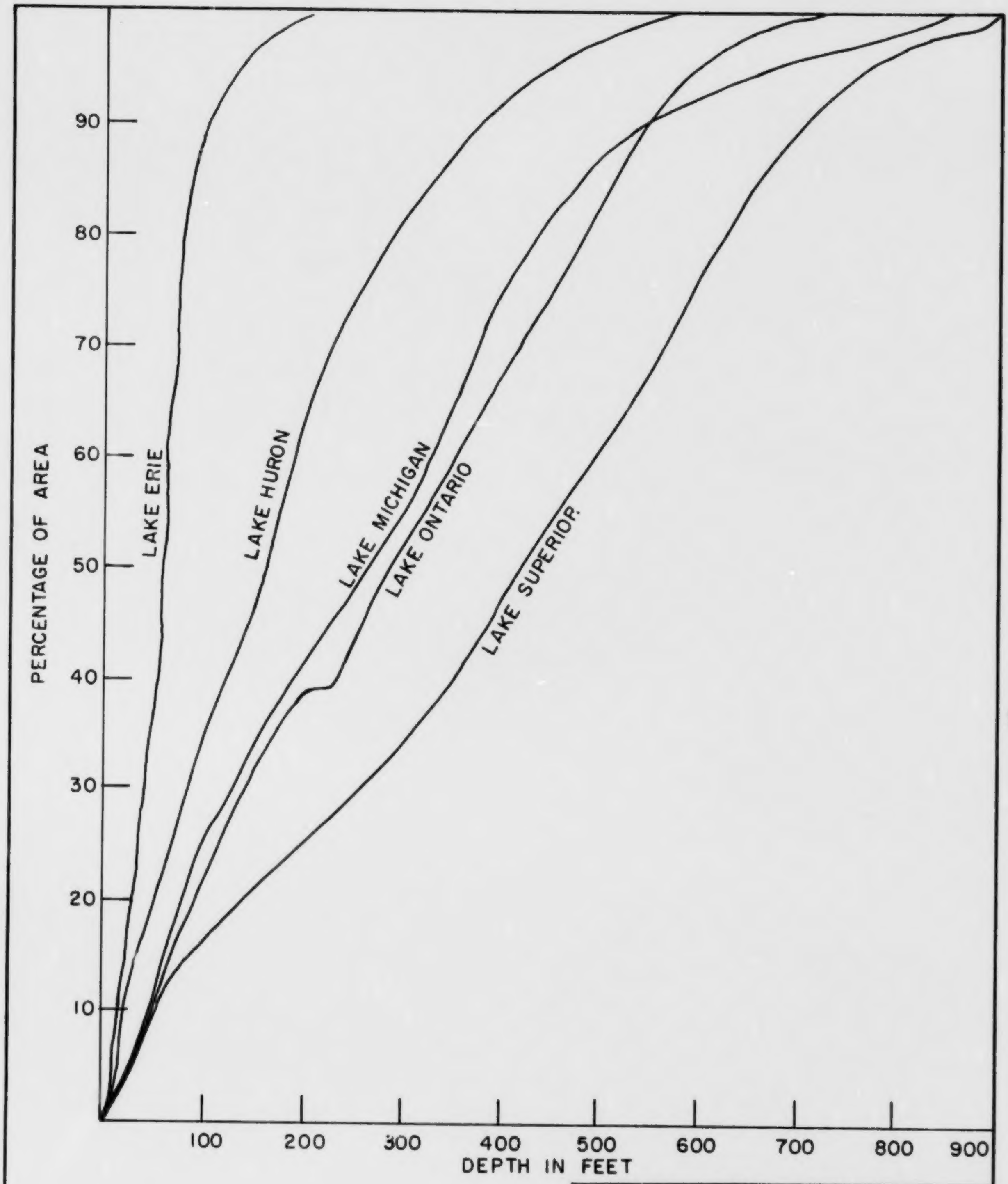


GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE ONTARIO & TRIBUTARIES
DEPTH-AREA CURVES
0-100 FEET

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 5

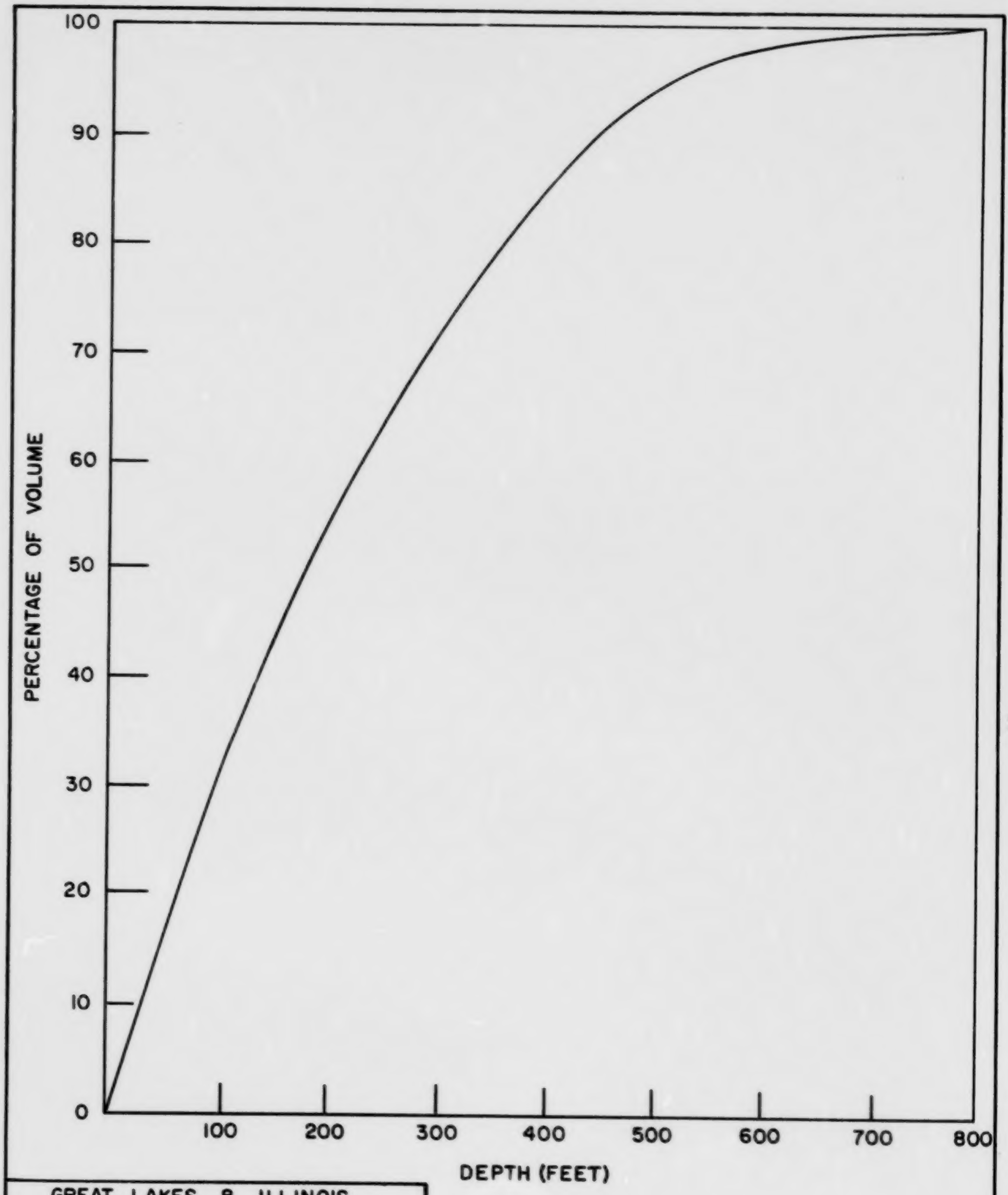


GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE ONTARIO & TRIBUTARIES
DEPTH-AREA CURVES
0-900 FEET

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 6



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE ONTARIO & TRIBUTARIES

DEPTH-VOLUME CURVE

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 7

the thermocline does not deepen rapidly. Surface temperatures reach a maximum in August, at which time the thermocline has reached a depth of 75 feet. In portions of the eastern basin, conditions may be homothermous to 100 feet in August, probably due to mixing caused by an active local current pattern. Differences as great as 23°C. (41°F.) between the sruface and bottom water may occur in the deeper waters of Lake Ontario, where the bottom waters do not warm above 4°C. (39°F.). Cooling of the surface waters occurs in September, but the thermocline remains stable. By late November there is less than 3°C. difference between the temperature of the epilimnion and hypolimnion. The temperature changes in the spring and again in the fall are partially responsible for vertical circulation or "turnover" which occurs at these times.3/

Lake Ontario is unique among the Great Lakes in that ice conditions during the winter do not seriously hamper shipping. During the severe winter of 1933-34 the lake was still open ten miles off the Rochester, New York, harbor.4/ It is considered unusual for more than 60 percent of Lake Ontario to be ice covered except in the most severe winters. This is probably due to the great depth, its southerly latitude, and the presence of fast currents.5/ In late winter the lake waters are thermally the most homogeneous. Gradual warming begins in April and continues through the spring and summer. Warming progresses somewhat faster in the shallow waters along the shore. These waters may be 2°C. (3.6°F.) higher than those in the open lake. On the southern shore considerably more warming is experienced and 20°C. (68°F.) water may be found near the mouth of the Niagara River.

Light Penetration and Transparency.--Lake Ontario has probably not undergone a decrease in transparency, although no early data are available for comparison. A series of secchi disc measurements made during the summer of 1965 averaged 3.5 meters for the entire lake. This is close to the average of 4.5 meters for Lake Erie, but considerably less than the 6 to 10 meter average of the other Great Lakes.[6]

Currents.--[1] The main current of Lake Ontario is in an easterly direction along the southern shore. A secondary current, though weaker, returns along the northern shore of the lake. From June to November, the western end of the lake has a circular current which is counterclockwise in direction. This current tends to increase the retention time for any pollutants discharged into the western end of the lake. In effect, the main flow from the Niagara River makes up the stronger south shore current but it also adds to the circular motion of the western current. The eastern end of the lake has the predominant current flowing in a northeast direction toward the St. Lawrence River outlet.

Through a change in wind direction, air and water temperature, or spring or fall overturn, the current pattern in the lake changes. With fall overturn, the current changes to the east. This suggests that a westward bottom current forms, causing the upwelling at the western end of the lake. This action flushes some of the accumulated sediments (including pollutants) from the lake bottom.

The changes in wind direction and velocity are of major importance in determining currents. Through spring and summer, the wind is from the west-southwest. Fall and winter winds are from the northwest, and average several miles per hour faster.

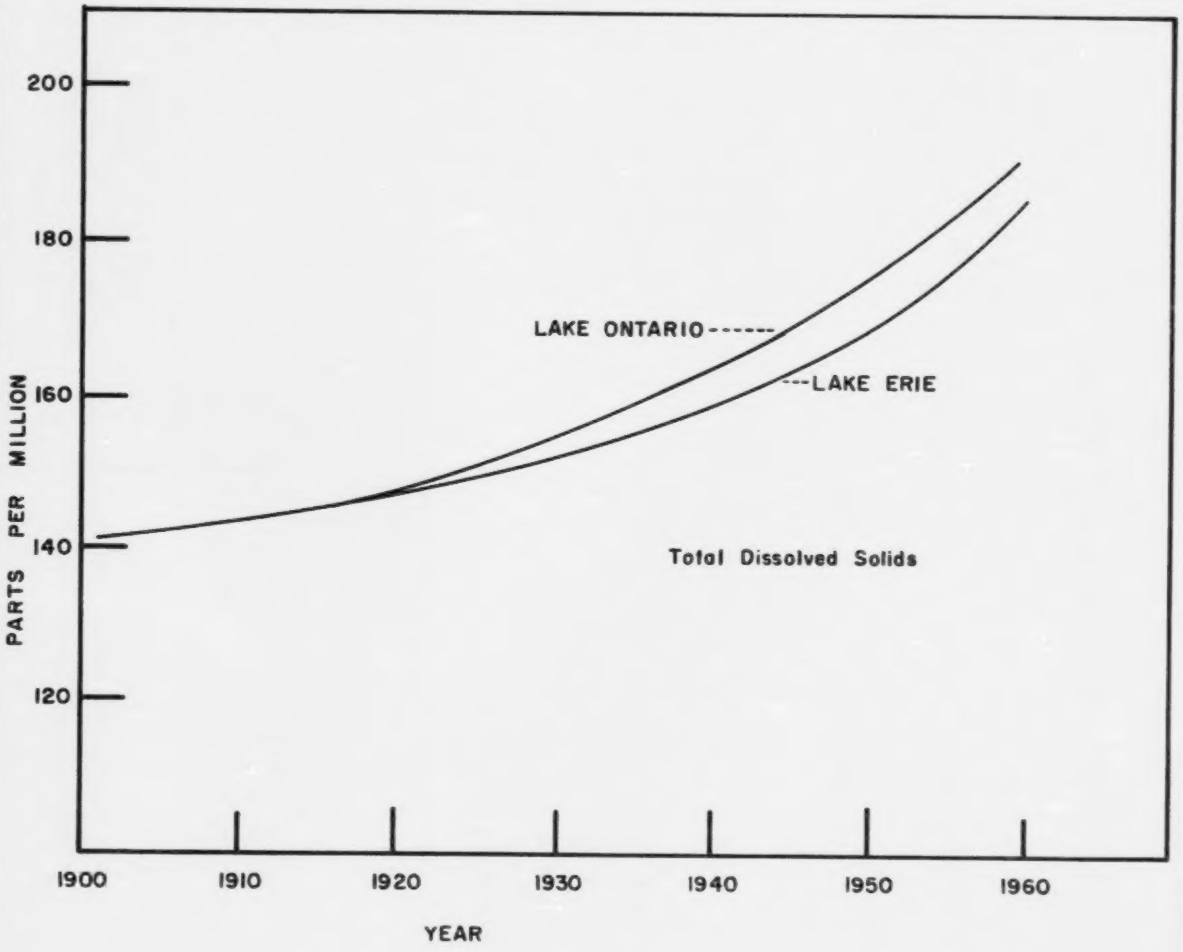
These characteristics are important in the distribution or concentration of pollutants in any area of the lake. Fish and wildlife can be subjected to dangerous levels of pollution during certain times of the year. This can be particularly serious when it occurs during spawning season or when vulnerable young are involved.

Chemical Characteristics.--[1] Lake Ontario waters are bicarbonate (average alkalinity, as calcium carbonate, 100 ppm) and are similar to the average fresh waters of the world. The average pH is 8.5 and the specific conductance is 272 micromhs at 18°C. (64°F). Sulfate concentrations (32 ppm) exceed chloride (24 ppm). Calcium, magnesium, sodium, and potassium concentrations are 39, 9, 11, and 1.2 ppm, respectively.

In general, the concentrations of the major cations and anions show little variation west to east or seasonally. Silica concentrations are low (0.2 to 0.3 ppm) near the surface due to a high productivity of diatoms, but increase with sampling depth reaching concentrations in excess of two ppm near the bottom. Limited data are available for phosphorus and nitrogen nutrients in the open waters of Lake Ontario. Data for samples collected in the fall of 1964 show a range of 17-130 ppb of total phosphorus (p) with most samples in the 20-40 ppb range.

Any discussion of the chemistry of Lake Ontario must include a discussion of the chemical characteristics of Lake Erie water because most of Lake Ontario's water originates in Lake Erie. Increases in the concentration of total dissolved solids, calcium, sodium-plus-potassium, and chloride in Lake Ontario (Figures 8 and 9) have closely paralleled those increases in Lake Erie. Sulfate has increased slightly more in Lake Ontario than in Lake Erie (Figure 9). Much of the increase in chemical content of Lake Ontario water is attributable to the increases in the chemical content of Lake Erie water and to wastes discharged into the Niagara River. Were this not the case, the increases for Lake Ontario of the concentration of the parameters shown in Figures 8 and 9 would not parallel so closely those of Lake Erie. However, all of the increase does not originate from Lake Erie and the upper Niagara River. Many of the tributaries to Lake Ontario, especially the Black, Oswego, and Genesee Rivers, are highly polluted.

Widespread oxygen depletion is characteristic of Lake Erie, but does not occur in Lake Ontario, although there are local exceptions



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE ONTARIO & TRIBUTARIES
TOTAL DISSOLVED SOLIDS
(FROM BEETON, 1965)

U.S. DEPARTMENT OF THE INTERIOR
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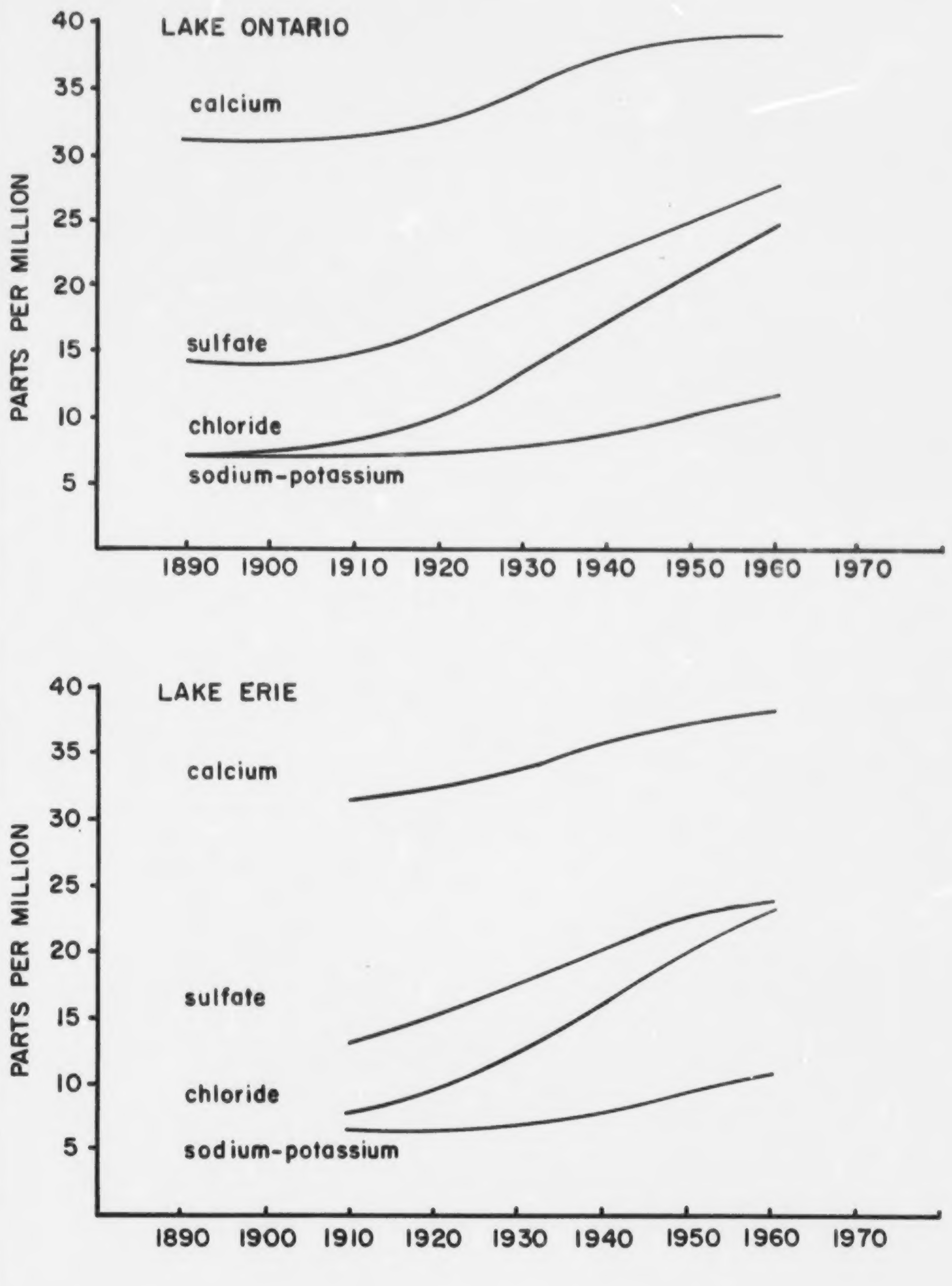
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 6



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE ONTARIO & TRIBUTARIES
CHEMICAL CHANGES
(BEETOM, 1965)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 9

such as the Bay of Quinte. The oxygen in the hypolimnion of Lake Erie has been shown to be consumed by sediments with high oxygen demands, and not from the BOD of the water. The central basin of Lake Erie is relatively shallow. Therefore, the thermocline over a large area of the basin is 10 feet or less from the bottom. Only near shore in Lake Ontario does thermal stratification occur this near the bottom. Even where Lake Ontario's sediments have a high oxygen demand, the reservoir of oxygen in the hypolimnion is too great for the sediments to materially reduce it during the few months when stratification is present.

Plankton.--Data accumulated at the Toronto Island Filtration Plant indicate that the phytoplankton doubled from 1923 to 1954. This period was characterized by a well-defined spring maximum and a well-defined winter minimum. Fall maxima were inconsistent and lower than spring maxima. The summer months were characterized by short, lesser pulses. A pulse is defined as a plankton count at least 2 times the annual mean. During the entire period, diatoms were the dominant organisms.

There was a change, however, in dominance among the diatoms during the spring pulses. Asterionella was the dominant genus until 1937. After 1938, Melosira became more prominent and increased in importance during the succeeding vernal pulses. Cyclotella increased in numbers after 1941 and was the dominant genus in 1950, 1952, and 1954.

During the fall of nearly every year, August to October, *Fragilaria* was dominant. However, its abundance was not great enough to constitute a pulse. *Tabellaria* occasionally increased in numbers at this time.

Both the summer and winter seasons were characterized by low levels of a population of mixed diatoms. Among the blue-green algae, *Anabaena* and *Oscillatoria* were occasionally present. The flagellates were represented by *Dinobryon*, which occurred frequently, with sporadic appearance of *Synura* and *Mallomonas*.

Recent samplings have revealed a change in phytoplankton composition, indicative of nutrient enrichment. A 1965 survey showed that the phytoplankton population of Lake Ontario varied from 50 to 3600 organisms/ml. Although these figures are considered to be moderate for biological activity, the dominant alga in the spring pulse (May) was *Scenedesmus*, and in July and September was *Chlamydomonas*. Both genera are indicators of nutrient enrichment and are not found in any other of the Great Lakes except Lake Erie. In mid-July a bloom of the blue-green alga, *Anabaena*, occurred. Its intensity was recorded at 10,000 organisms/ml.

As of the 1965 study, the predominant algae of Lake Ontario had changed from diatoms to green algae. This is a change from clean water species to species characteristic of nutrient enrichment.[1/]

Although *Cladophora* is not a plankter, it is an alga that had reached nuisance proportions by the 1930's. In a 1963 study by

Neil and Owen, the distribution of Cladophora was found to be concentrated on the northern shore of Lake Ontario from the south shore of Prince Edward County to the Niagara River. A 1965 survey showed Cladophora to be distributed on all shores of Lake Ontario wherever suitable substrate occurred. Windrows of this decaying algae have been noticed on many beaches which have been rendered unsuitable because of the obnoxious odor and appearance. Problems have also occurred with water supply intakes along the lake.[1]

Benthic Organisms.--Of the seven principal types of benthic organisms present in Lake Ontario, two constitute about 95 percent. These two are Amphipoda (scuds) and Oligochaeta (sludgeworms). The remaining five percent are Sphaeriidae (fingernail clams), Tendipedidae (blood-worms), Isopoda (aquatic sow bugs), Mysidacea (opossum shrimp) and Hirudinea (leeches). Amphipoda are the predominant organisms throughout the lake. The ranges in number of organisms per square meter varied from 0 to 5,400 in all deep water during all phases of the 1965 study.[1]

There is a definite difference in bottom fauna when compared to the major harbor areas, such as the Niagara, Genesee, and the Oswego River harbors. In these harbors, the pollution-tolerant organisms are abundant, while those species needing clean water are absent. This situation would indicate that these rivers contribute to the degradation of water quality in these areas.

Evaluation of biological conditions in Lake Ontario shows a tendency towards eutrophic conditions. The benthic fauna indicates oligotrophic conditions. However, the phytoplankton and attached algae problems that occur tend to support a eutrophic nature. Deep water is apparently the one major factor that saves Lake Ontario from becoming eutrophic.[1]

TRIBUTARY STREAMS

The characteristics of basin lands and waters, including the streams and rivers draining the watershed, greatly influence the habitat base which supports all fish and wildlife. Table 3 identifies the major subbasins tributary to Lake Ontario and their drainage areas.[1]

Table 3. Principal United States Rivers Tributary to Lake Ontario

Stream	Drainage Area (sq. mi.)	Average Discharge (cfs)
Niagara River	1,688	203,000
Genesee River	2,497	2,739
Oswego River	5,000	6,320
Black River	1,916	3,872
Total:	11,101	215,931

For purposes of this report, only that portion of the Niagara River from Niagara Falls to Lake Ontario is included in the Lake Ontario Basin. The portion of the Niagara River upstream from the Falls was included in a previous report as part of the Lake Erie drainage. Most of the subbasin is made up of small drainage systems, composed of small streams along the southwest shore of Lake Ontario. This system is bounded on the east by the Genesee River subbasin.

The Genesee River and its tributaries drain a small portion of western New York and a very small part of northern Pennsylvania. The basin is about 100 miles long and has a maximum width of 40 miles. The river rises in Pennsylvania, flows northwesterly into New York and enters Lake Ontario at Rochester, New York.[7]

The Oswego subbasin lies to the east of the Genesee River. The subbasin includes several small watersheds along Lake Ontario. The Oswego is the principal river and is formed by the junction of the Seneca and Oneida Rivers. The Oswego River has been canalized and it passes through several locks and dams in its 23-mile flow to Lake Ontario. (Photo 1)[8]

The Black River drains a portion of the Adirondack Region of northern New York. This basin adjoins the St. Lawrence River Basin on the north and east. The river rises in North Lake and flows about 100 miles to its confluence with Lake Ontario at Black River Bay.[9]

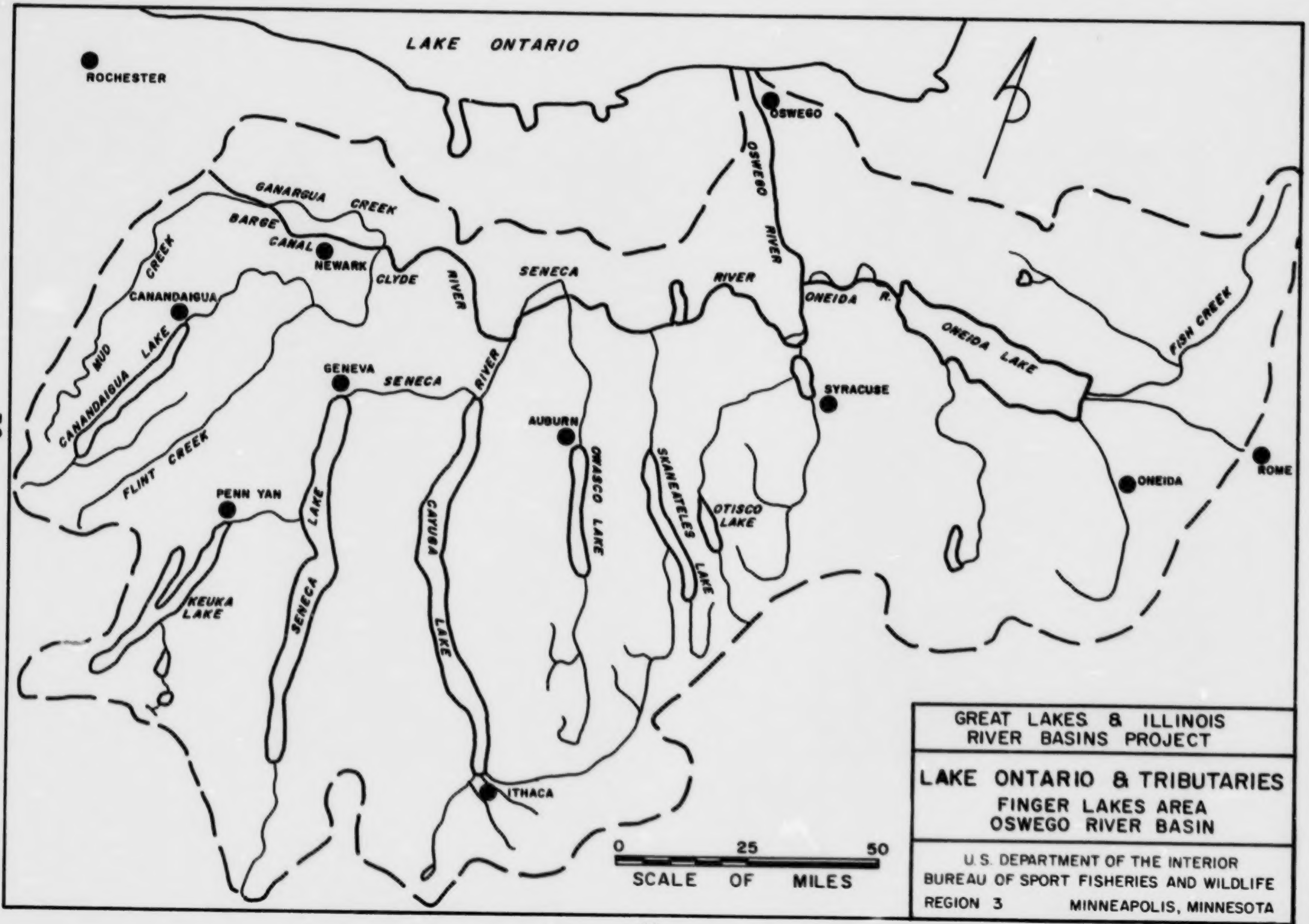
Numerous smaller tributaries to Lake Ontario form an important network of streams along the southern and eastern shore of the lake (Photo 2). Except for basins of the previously mentioned larger tributaries, these smaller drainages form an interrupted belt 8 to 31 miles in width from the Niagara River to the St. Lawrence River.

INLAND LAKES

The United States portion of the Lake Ontario Basin contains a larger and more diversified inland lake habitat than any of the other Great Lakes Basins. It includes not only the large and well known Finger Lakes but almost a dozen moderately-sized lakes ranging from Hemlock, Coneseus, and Honeoye in the west, through Onondaga and Neatahwanta in the central portion to the landlocked embayments of North and South Sandy Ponds (Table 4). These habitats vary for the deep, essentially eligotrophic conditions prevailing in Lake Seneca, the deepest of the Finger Lakes, to the extremely fertile, eutrophic situation characteristic of shallow Lake Oneida (Figure 10). Some of the deeper Finger Lakes support significant populations of lake and rainbow trout. Others exhibit an intermediate fish population structure with some trout, but largely dominated by warm-water species. The remainder are warm-water lakes with varying combinations of walleye, bass, and pan fish (Centrarchidae). Carp and other coarse fish make up a large portion of the population in some cases. Lake Onondaga, the most heavily polluted of the inland lakes, still supports walleye and northern pike but their flesh is unpalatable.

Photo 1. Oswego Harbor, New York

Photo 2. Sodus Bay, New York


LAKE ONTARIO
ROCHESTER
OSWEGO
GANARGUA CREEK
BARGE CANAL
NEWARK
CLYDE RIVER
SENECA RIVER
OSWEGO RIVER
ONEIDA R.
ONEIDA LAKE
FISH CREEK
MUD CREEK
CANANDAIGUA
CANANDAIGUA LAKE
GENEVA
SENECA
RIVER
AUBURN
SYRACUSE
ROME
ONEIDA
FLINT CREEK
PENN YAN
SENECA LAKE
CAYUGA LAKE
OWASCO LAKE
SKANEATELES LAKE
OTISCO LAKE
KEUKA LAKE
ITHACA
0
25
50
SCALE OF MILES

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE ONTARIO & TRIBUTARIES
FINGER LAKES AREA
OSWEGO RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 10

Table 4. Principal Inland Lakes in the Lake Ontario Basin

Lake	Drainage Area (Square mi.)	Surface Area (Square mi.)	Maximum Depth (ft.)
Otisco*	34	3.5	66
Skaneateles*	73	13.8	300
Owasco*	208	10.4	177
Cayuga*	813	66.4	435
Seneca	707	66.7	618
Keuka*	178	17.5	183
Canandaigua*	175	15.6	274
Oneida	1,265	80	55
Onondaga	301	4.5	60
Conesus	72	5.1	66
Hemlock	-	2.9	88
Canadice	12.6	.97	80
Honeoye	197	2.6	30

*Finger Lakes

All of these lakes probably contributed to at least a localized commercial fishery at some time in the past, although the records are not detailed enough to be very definitive on this point. In Oneida Lake commercial fishing consisted of removal of common suckers (*Catostomus commersonii*), American eels, carp, brown bullheads (*Ictalurus nebulosus*) and channel catfish (*Ictalurus punctatus*). Walleyes (*Stizostedion vitreum*) caught with hook and line were legally sold by fishermen in considerable numbers until a few years ago. Breeding suckers were taken during the early part of the century in the spring by means of long seines dragged at the outlet of the lake. In 1903, 300 tons were taken in this manner. The seining was done in late afternoon, or more frequently at night, with hauls once every hour yielding 1,000 or more fish per attempt. This fishery died out around 1915. Carp control measures were initiated in 1927 by granting permits to commercial seiners. The program was ineffective in decreasing the carp population because, except for one operator, relatively few fish were taken.[10/] The food fish needs generated by World War II resulted in some food fish removal from Lake Oneida. This fishery continued into the post-war years, as indicated in Table 5. The principal species in this removal was carp. It is possible that some limited catches were also made on other fertile lakes such as Neatahwanta and portions of the Oneida and Oswego Rivers.

Some commercial fishing is still carried out on Oneida Lake. One fisherman is licensed to seine carp and white bass, and he reported a catch of 52,000 pounds of carp and a minimum of 400 pounds of white bass in 1968. Licenses are also issued for set lines in Oneida Lake, and significant numbers of channel catfish are caught and marketed. However, records of this catch are not available.[11] Except for this and some occasional removal work by State crews, there is no longer a commercial fishery in these inland lakes.

Table 5. Commercial and Rough Fish Removal Program in Lake Oneida

Year	Netted by Commercial Fishermen Under State Contract	Netted by Commercial Fishermen and Disposed of on Open Market	Netted by Salvage Units (part-time)
1949	77,556	15,160	3,000
1950	83,640	16,480	none
1951	66,582	10,816	none
1952 (to date 8/6/52)	68,889	9,465	none

FISH AND WILDLIFE RESOURCES

FISHERY BASE

Less is known of the past history and population dynamics of Lake Ontario fish than of any of the other Great Lakes.

Although the commercial fish production of Lake Ontario throughout the period of record has been relatively low in comparison with the other lakes, particularly its fertile neighbor, Lake Erie, the annual catches have contributed significantly to Great Lakes production.

At the time of earliest settlement, Atlantic salmon (*Salmo salar*) were plentiful. They spawned in most of the streams along the north shore and in the Salmon and Oswego Rivers on the southern shore. The Salmon River, according to early reports, supported the best Lake Ontario runs in United States waters, with as many as 300 salmon being taken by one fisherman in a single night's fishing. This pressure, plus construction of dams on the spawning tributaries, resulted in steady fishery decline until the Lake Ontario salmon became entirely extinct sometime between 1880 and 1900. Study of the scales from museum specimens indicates that these salmon were a landlocked form that did not ascend the St. Lawrence River from the sea.

Whitefish (*Coregonus clupeaformis*) and lake trout (*Salvelinus namaycush*) were also commercially taken from the earliest times.

A considerable number of sturgeon (Acipenser fulvescens) and lake herring (Coregonus artedii) were caught but were considered to have no value at the time and were destroyed. Later the lake herring became important in the commercial fishery. The sturgeon had virtually disappeared by the time its commercial potential began to be appreciated. As the fishery developed, blue pike (Stizostedion vitreum glaucum), chubs (Coregonus sp), walleye (Stizostedion vitreum vitreum), yellow perch (Perca flavescens), and eels (Anguilla bostoniensis) began to be harvested in increasing numbers. Late in the 19th century, the carp (Cyprinus carpio) was introduced, followed by the smelt (Osmerus mordax) in the 1940's, and the white perch (Roccus americana) in the 1950's (Scott 1963). These species have since become a significant part of the total fish stocks, with the carp, white perch and smelt entering into the commercial fishery. It is not definitely known whether the alewife (Alosa pseudoharengus) was indigenous to Lake Ontario or came in as an invader, as was the case in the other Great Lakes. In any event, the species has been abundant in Lake Ontario since at least 1890.

During the first three decades of the 20th Century, the basic resource apparently reached some sort of equilibrium with man's influence and limited biological changes such as the appearance of the carp, and possibly the alewife (Table 6). The commercial fishery maintained itself in a fairly flourishing condition. Although the Atlantic salmon and sturgeon had passed from the

Table 6. Average Combined Production (Thousands of Pounds) of Certain Species for Specified Periods in the Commercial Fisheries of the United States and Canadian Waters of Lake Ontario, 1879-1966

Period	Lake Herring 2/	Sun-fish 3/	White-fish	Lake Trout	Smelt	Carp	Yellow Perch	Wall-eye 4/	Blue Pike 4/	Cat-fish 5/	Bull-heads 5/	Am. Eel	No. Pike	Other
1879-09 1/	2,028	--	623	267	--	21	411	337	--	531	--	130	350	819
1910-19 1/	1,759	--	1,128	555	--	175	147	38	88	265	--	188	--	841
1920-29	1,010	--	1,986	780	--	118	125	100	75	177	--	150	130	547
1930-34	1,185	--	558	349	--	94	140	37	162	234	--	106	168	326
1935-39	1,430	--	672	257	--	415	208	26	125	239	--	84	108	411
1940-44	1,382	--	471	116	--	392	190	26	121	166	--	52	70	346
1945-49	557	--	336	68	--	212	185	38	179	415	--	61	60	394
1950-54	152	227	355	23	271	289	118	84	298	29	491	64	24	124
1955-59	53	191	393	2	239	433	78	137	27	28	441	115	31	197
1960-64	51	160	391	3	182	351	217	102	1	23	253	185	44	220
1965	31	159	121	--	202	334	477	51	*	27	164	214	21	1,062
1966	39	138	59	--	141	317	170	48	*	27	125	178	22	597

1/ Averages for years of record.
2/ Catches combined with chubs through 1951; chubs are not caught in significant quantities.
3/ Catch from Canada not available until 1952.
4/ Catches combined through 1918.
5/ Catches combined through 1952.
* Less than 500 pounds.

scene, the cold-water complex still retained the lake trout, whitefish, lake herring, and chubs as important contributors during this period. The higher value warm-water species such as the blue pike and yellow perch remained at a high production level, with some input from walleye and the introduced carp.

The gross commercial harvest from this composite fishery reached a peak in 1917 with landings totaling 5.5 million pounds. Whitefish and lake trout harvests reached 2.6 million and just over 1 million pounds, respectively, in the mid-1920's. As late as 1940, lake herring production reached 1.5 million pounds.

In recent years, cold-water commercial fish production has declined considerably. The take of lake trout is now prohibited. Commercial whitefish production is now restricted to the eastern end of the lake. Since 1930, whitefish production has exceeded half a million pounds during only two years.

The blue pike has been lost commercially, if not biologically, to the Lake Ontario fishery complex. During the last few years there has been a tremendous increase in the white perch population, and this species has dominated the warm-water commercial catch with carp and yellow perch the only other species of significance (Table 7). A popular recreational fishery exists in the island areas of the eastern basin, the St. Lawrence River, and the Bay of Quinte. Smallmouth bass (Micropterus dolomieui), yellow perch,

Table 7. United States Commercial Production in Lake Ontario, 1966

(Pounds)

Species	Chaumont Bay	Lake Ontario Proper	Grand Total
Whitefish	104	2117	2221
Herring	256	2502	2758
Walleye	2644	1285	3929
Smelt	71	90	161
Eels	35305	--	35305
Sturgeon	100	--	100
Blue pike	--	9	9
Yellow perch	13933	1334	15267
Suckers	9281	1092	10373
Carp	15241	--	15241
Catfish	584	--	584
Bullheads	27354	83	27437
Sheepshead	80	--	80
Dogfish	1520	--	1520
Ling	19	--	19
Sunfish	12347	--	12347
Rock bass	6765	748	7513
Calico bass	1345	--	1345
Silver bass	859	--	859
White perch	5051	95047	100098
Total:	132,859	104,307	237,166

northern pike (Esox lucius), muskellunge (Esox masquinongy), and walleye are the principal species involved in this fishery.

Lake Ontario supports large populations of species such as alewives and smelt, which are essentially unused commercially. Smelt support a heavily used sport fishery during their spawning runs, however.

The reasons for the limited productivity of the Lake Ontario commercial fishery, in contrast to the other Great Lakes, are not fully understood. Introduction of new species and poor markets for abundant but low-value species has also worked against the commercial fishery of other lakes. It seems apparent that excessive harvest of lake trout over very restricted spawning areas has had severely adverse effects and may largely account for declines in this species. Limnological changes due to man's influence have also had an influence which is discussed in greater detail later in this report. However, other Great Lakes have had similar changes which, in some cases such as Lake Erie, have had greater impact. Morphological considerations are sometimes cited to account for Lake Ontario's low productivity. While great depths do prevail over much of the lake, Figures 5 and 6 indicate that Lake Ontario has roughly the same percentage of shallow, shoal water as Lake Michigan and a greater percentage than Lake Superior, thus casting considerable doubt on this explanation.

Sport fishing in Lake Ontario, on the many tributary rivers, or on the inland lakes, provides high quality recreation near large population centers. This fishery is made up of both warm-water and cold-water fishes. Table 8 gives a list of the sport fish sought in the Lake Ontario Basin.

There is little variation in preferred species when the various subbasins of the Lake Ontario watershed are compared. Walleye, smallmouth and largemouth bass, and several species of pike and trout are the most popular fish throughout the basin.

Most of the streams and lakes are rich in nutrients and produce good populations of fish. The Finger Lakes are famous for their fishing as well as their beauty. Seneca and Cayuga Lakes, the largest of the Finger Lakes, are good examples of the high quality environment to be found in the area. Seneca has a reputation for producing record rainbow trout and for outstanding lake trout fishing.[12/] Cayuga Lake is gaining in popularity.[13/] The other Finger Lakes, plus many smaller lakes, provide extensive sport fishing opportunities. Oneida Lake, the largest lake entirely within New York, is considered one of the most productive lakes on this continent.[2/] The river systems of the St. Lawrence River subbasin have their sources in the Adirondack Mountains of northeastern New York. This area is lightly populated in comparison with the rest of the basin. The subbasin provides many miles of remote streams and numerous lakes, most with fishable populations.[14/]

Table 8. Sport Fish in the Lake Ontario Basin*

White perch	*Roccus americanus*
White bass	*Roccus crysops*
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum vitreum*
Blue pike	*Stizostedion vitreum glaucum*
Chain pickerel	*Esox niger*
Northern pike	*Esox lucius*
Muskellunge	*Esox masquinongy*
Rock bass	*Ambloplites rupestris*
Largemouth bass	*Micropterus salmoides*
Smallmouth bass	*Micropterus dolomieui*
White crappie	*Pomoxis nigromaculatus*
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Bullheads	*Ictalurus sp.*
Lake whitefish	*Coregonus clupeaformis*
Ciscoes	*Coregonus sp.*
Smelt	*Osmerus mordax*
Lake trout	*Salvelinus namaycush*
Rainbow trout	*Salmo gairdneri*
Brook trout	*Salvelinus fontinalis*
Brown trout	*Salmo trutta*
Coho salmon	*Oncorhynchus kisutch*
Chinook salmon	*Oncorhynchus tshawytscha*
Kokanee salmon	*Oncorhynchus nerka*

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*American Fisheries Society Special Publication #2, 1960.

Lake Ontario provides sport fishermen with smallmouth bass, northern pike, walleye and rainbow trout fishing along with many additional game species. Recent introduction of kokanee, coho, and chinook salmon and splate trout may add considerably to the fishing in the near future. Although most of the shoal areas are fished, the eastern end of the lake is the most productive.

The sea lamprey (Petromyzon marinus), whose recent invasion of the Upper Lakes has been a major catastrophe to their fisheries, has always been present in Lake Ontario. While a biological balance may have been achieved, lamprey predations still continue to exert at least a peripheral influence upon fish population dynamics. This influence may be one of making the fishery base more vulnerable to the effects of other influences, including environmental change. Basically, however, most analysis of the dynamics of the fishery base is largely speculative. There is a real need for more study and investigation to obtain a sound basis for management.

WILDLIFE BASE

General.--All wildlife is affected to some degree by water quality, either directly or indirectly. Water quality may become a critical factor for water-oriented species. In some parts of the Lake Ontario Basin, degraded water conditions have resulted in changing environments effecting major changes in wildlife species composition and numbers.

The distribution and variety of game in the Lake Ontario Basin offers the New York hunter many hunting opportunities. Waterfowl, grouse, squirrels, pheasants, rabbits, hare, deer, and bear are the principal species hunted in the basin. Well over half of the hunters take upland game in the basin. Highest rates of success are provided by squirrels, rabbits, and waterfowl--in that order.

Waterfowl of the Lake Ontario Basin are within the Atlantic Flyway, one of four such flyways in the United States. The principal nesting and resting areas in the Lake Ontario Basin are Montezuma and Iroquois National Wildlife Refuges, the Finger Lakes complex, the State Oak Orchard and Tonawanda Game Management Areas, and the marshes and ponds along the Lake Ontario shoreline.

Historical Background.--Wildlife resources in the Lake Ontario Basin have long been both abundant and varied. In the past century, however, there have been many changes. Diaries of soldiers in the Iroquois Indian Wars of 1779 contained references to the vast tall grass prairies of the Genesee River Flats. Those prairies have long since disappeared, having given way to fire and the plow.

From the 1820's to the 1880's, land clearing and farm building activities were at their height. Vast areas of timber were cleared for farmland. More recently, with the advent of modern forestry, reforestation has become important. The trend toward denuding of the land has gradually reversed. Reverting farm lands to reforested areas now provide essential habitat for wildlife, thereby enabling many forest dwelling species to survive. For example, the much greater volume of browse which has become available to white-tailed deer has allowed deer herds to increase to far greater numbers than the primeval forests were ever able to carry. The cottontail rabbit expanded its range and numbers as openings were created in the forests.

Niagara River Subbasin.--The wildlife resources of this subbasin consist principally of farm game and waterfowl. Ideal habitat provided by grain fields, orchards and protective hedgerows help sustain good populations of upland birds.

Distribution of wildlife resources in the Niagara River Basin has developed in harmony with the Lake Plain physiographic division. It is characterized by an expanse of flat, fertile, agricultural land. Wildlife species of importance in this region are the ring-necked pheasant and the cottontail rabbit. Pheasant numbers fluctuate greatly, making the cottontail rabbit the most important small game species in this area in terms of numbers bagged. Squirrels are not numerous throughout this zone, but they are locally abundant, principally in farm woodlots. White-tailed deer are present, but populations are generally low.

Aquatic wildlife, including waterfowl, shore and marsh birds, mink, beaver, muskrats, raccoon, and otter, depend upon the rivers, streams, lakes, and natural wetlands for their existence. Suitable habitat occurs in scattered marshes along the Niagara River and along the Lake Ontario shore.[15] Many marshes have been created or restored for waterfowl by the New York Conservation Department. The 1954 inventory of permanent water areas of significance to waterfowl delineated all permanent water areas of the State, regardless of size or location.[16]

Genesee River Subbasin.--A 1951 fish and wildlife resource inventory of the Genesee River Basin revealed that some of New York's finest agricultural habitat is in this basin.[18] Wildlife species of importance include the ring-necked pheasant, gray squirrel, white-tailed deer, and cottontail rabbit. Generally, farm-game habitat is better in that part of the lake-plain area below 1,000 feet (m.s.l.).[19] Woodchuck hunting is also a popular sport in this area. Wildlife resources of the basin are generally adequate to satisfy hunter demand. However, waterfowl are in short supply and most hunting is done on private marshes. Wildlife habitat in the basin is being seriously threatened by urbanization and other changing land uses.

Productive muskrat marshes occur throughout most of the basin, except in the headwater areas where it is scarce. Good muskrat habitat is situated along the ends of the "Little Finger Lakes" (Conesus, Canadice, Honeoye), and in farm ponds. Oxbows along Canaseraga Creek, the Genesee River, and some of the slower, more stabilized stream courses provide good muskrat trapping.

Oswego River Subbasin.--This basin, with its diversity of wildlife habitat, supports rich and varied wildlife resources. It includes some of the better agricultural wildlife habitat in the state.[10] Upland game in the Oswego River Basin consists principally of ring-necked pheasants and cottontail rabbits. Swamps, marshes, woodlots, and reverted brush or forest lands provide excellent cover. Hunting pressure is heavy and harvest is high.

A large area in the northeastern part of the basin provides forest-wildlife habitat for white-tailed deer, ruffed grouse, gray squirrel, snowshoe hare, and woodcock. Furbearers such as red fox, gray fox, mink, raccoon and otter are also found here.

Wetlands and other aquatic habitat in the basin are of high value to waterfowl and fur animals. This basin and the adjoining smaller tributary basins to the north contain some of the more important wetlands within the State of New York. The east-west line formed by the Seneca River and the Barge Canal is the axis of a large wetlands complex. Numerous small wetlands are scattered throughout the basin, adding to the value of the larger swamps and marshes. These smaller wetlands furnish breeding habitat for such species as black ducks, wood ducks, mallards, and blue-winged teal. The chief uses of the larger marshes are for resting areas for migrating waterfowl and nesting habitat for diving ducks.

The Finger Lakes and Oneida Lake (Photo #3) form natural waterfowl refuges, especially for diving ducks. Small marshes around the perimeter and between the lakes offer valuable nesting sites. Some of the most valuable marshlands are located in this region.

The Finger Lakes and Oneida Lake (Photo #3) form natural waterfowl refuges, especially for diving ducks. Small marshes around the perimeter and between the lakes offer valuable nesting sites. Some of the most valuable marshlands are located in this region.

Montezuma National Wildlife Refuge is one of over 270 Federal refuges in the nation (Photo 4). This refuge is a key unit in a refuge chain affording protection to Atlantic Flyway waterfowl. The refuge contains over 6,000 acres and is located at the north end of Cayuga Lake. Bird counts during the April to October period have recorded about 250 species using this refuge. Over 100,000 ducks and 25,000 geese have been counted during peak migration periods on Montezuma's marshes.

Black River Subbasin.--The farm-game resources in the Black River Basin are relatively unimportant. A few pheasants and rabbits range along bottomland areas of the river, but forest wildlife species predominate.

With the exception of urban areas and broad areas of pastures and croplands, the entire basin may be considered white-tailed deer habitat. The ruffed grouse is the most important small game species in the basin. These fine game birds range throughout the watershed. Fur animals in the basin include the beaver, muskrat, mink, red fox, gray fox, raccoon, bobcat, weasel, fisher, skunk, and otter. The muskrat is the most important in terms of catch, but the basin contains a relatively limited amount of habitat, at least in comparison with the other basins.

Photo 3. Oneida Lake, New York

Photo 4. Montezuma Marsh, New York

The Black River Basin is an unimportant waterfowl production area.[11] However, considerable numbers of waterfowl utilize flooded fields and river backwaters during spring migrations. Waterfowl hunting is of limited importance. It does not compare favorably with nearby St. Lawrence County which provides extensive waterfowl hunting.[14]

St. Lawrence River Subbasin.--The St. Lawrence River lowlands are located at the east end of Lake Ontario and extend to Massena, New York. Deer, grouse and squirrels are abundant in forest and woodlot edges in all parts of the basin. This basin also has a large well established population of Hungarian partridge, the result of State stocking programs. The St. Lawrence River and Black Lake are segments of the important Ontario-St. Lawrence waterfowl flyway. High value wetlands in the area total about 25,000 acres. All of the common species of marsh and diving ducks are taken here, with the black duck and wood duck being the most important.[14]

FISHERY MANAGEMENT

Efficient, sustained fishery yield requires good habitat, satisfactory fish stocks, and sound management. In analyzing the management base, the following considerations should be kept in mind as a framework guide.

1. Overall, the Great Lakes cannot be classified as productive waters in terms of historical fishery production per unit area. Lake Ontario, with its average annual commercial production of

approximately .1 pound per acre, has the lowest historical productivity per unit area of all the Great Lakes.

2. Sound management requires solid information on which to base decisions. This type of information has accumulated very slowly, and there are still many gaps in important areas of research knowledge.

3. In the past, management and manipulation of fish stocks in a resource block as large and diverse as Lake Ontario has had to rely primarily on indirect control, mostly in the form of regulation of both the commercial and sport harvest. More recently, direct management has become feasible on a scale never attempted before. This includes introductions of exotics such as coho, chinook, and kokanee salmon. The possibility of significant environmental alteration through large scale pollution abatement and major habitat improvements is now a real possibility.

The sea lamprey control program is also classified as direct management. Harvest manipulation will continue, however, to be the chief means to: (a) achieve maximum utilization of abundant stocks, (b) reduce undesirable or stunted stocks, (c) aid the recovery of temporarily depleted populations, and (d) allocate sport and commercial fishing use to achieve maximum overall benefit. Without adequate, continuous knowledge of changing biological and environmental conditions, this cannot be done.

4. Management perspectives must be based on the whole lake ecosystem, implemented by a system of regulations sufficiently flexible to adapt to rapidly changing biological and economic conditions. While Lake Ontario is less subject to multiple jurisdiction than any of the Great Lakes, it operates under a New York State Code in United States waters, with a separate code for Canadian waters. Research activity has tended to be fragmented and piecemeal. However, trends toward greater coordination and integration of management and research programs have been gradually developing. In 1946, a Lake Ontario Fish Management Committee was jointly established by New York and Ontario to exchange information and facilitate management decisions. In 1955, the Great Lakes Fishery Commission was established by treaty between the United States and Canada. The Commission is charged with the implementation of a program for control of the sea lamprey and coordination of fishery research by various agencies. Control of the sea lamprey is not the major problem in Lake Ontario that it is in the Upper Lakes, but coordination of management and research is very necessary. The pre-existing Lake Ontario Fish Management Committee became one of five Lake Committees within the overall structure of the Great Lakes Fishery Commission, thus continuing to provide a mechanism for consideration of problems specific to the lake. The Commission, with the assistance of Federal and State agencies engaged in fishery research and management, prepared a brief entitled "A Prospectus for Investigations of the Great Lakes

Fishery", which was submitted to the United States Government in July 1964. Many of the investigations proposed for Lake Ontario in this report are contained in that document.

5. Development of a sound fishery management base will require joint consideration of both commercial and sport fisheries. Although exact data are lacking on the extent of sport fishing, it is generally agreed that it is significant, particularly in the eastern end. Under proper management, the interests of both sport and commercial fisheries are complementary.

6. Management of sport fisheries can be approached in several ways. To be most effective, management must include programs to maintain high quality in existing streams and lakes. Improvement of habitat, fish stocking, and flexible fishing regulations are other tools of sport fish management. These latter methods of management will be effective principally on the smaller inland waters.20/

Stocking fish has always been a popular method of management. Michigan's recent success in planting the coho salmon has led other States to investigate their waters for introduction of potential exotic species. New York stocked about 25,000 coho salmon smolts in the Salmon River drainage in 1968. Additional stockings of coho were made by New York and Ontario in 1969. Chinook salmon fingerlings were stocked in the Little Salmon River drainage by New York in 1969. Kokanee salmon were stocked in the lake and in some tributaries by Ontario. Splake were introduced into the lake by Ontario in 1969. Kokanee and splake have been present for a number of years in some inland waters of the basin.

Lake Ontario originally supported landlocked salmon which provided the early settlers with food and sport, but man's activities soon exterminated these fish. Coho or other similarly popular species could boost the economy of surrounding communities by millions of dollars, a situation which has already occurred around Lake Michigan. A controlled commercial fishery is also possible.21/

WILDLIFE MANAGEMENT

Management of wildlife, in most cases, is aimed at those areas which are vulnerable and essential for maintenance of life. Proper food, habitat, and population balance are among these obvious management aims. Management of people, however, is also important to long-term considerations. Encroachment of suburban development, use of pesticides, and many other problems have to be controlled.

Since marsh areas and the immediate uplands surrounding the marsh are high producers of wildlife, many management efforts are made in these areas. Waterfowl, shore birds, aquatic and semiaquatic mammals, upland game, and big game are all dependent on high quality marsh habitat. The more important areas managed, or soon to be managed, in the Lake Ontario Basin are located on Figure 11.22/ Noteworthy among these is the Montezuma National Wildlife Refuge on the north end of Cayuga Lake. The Montezuma Marshes have

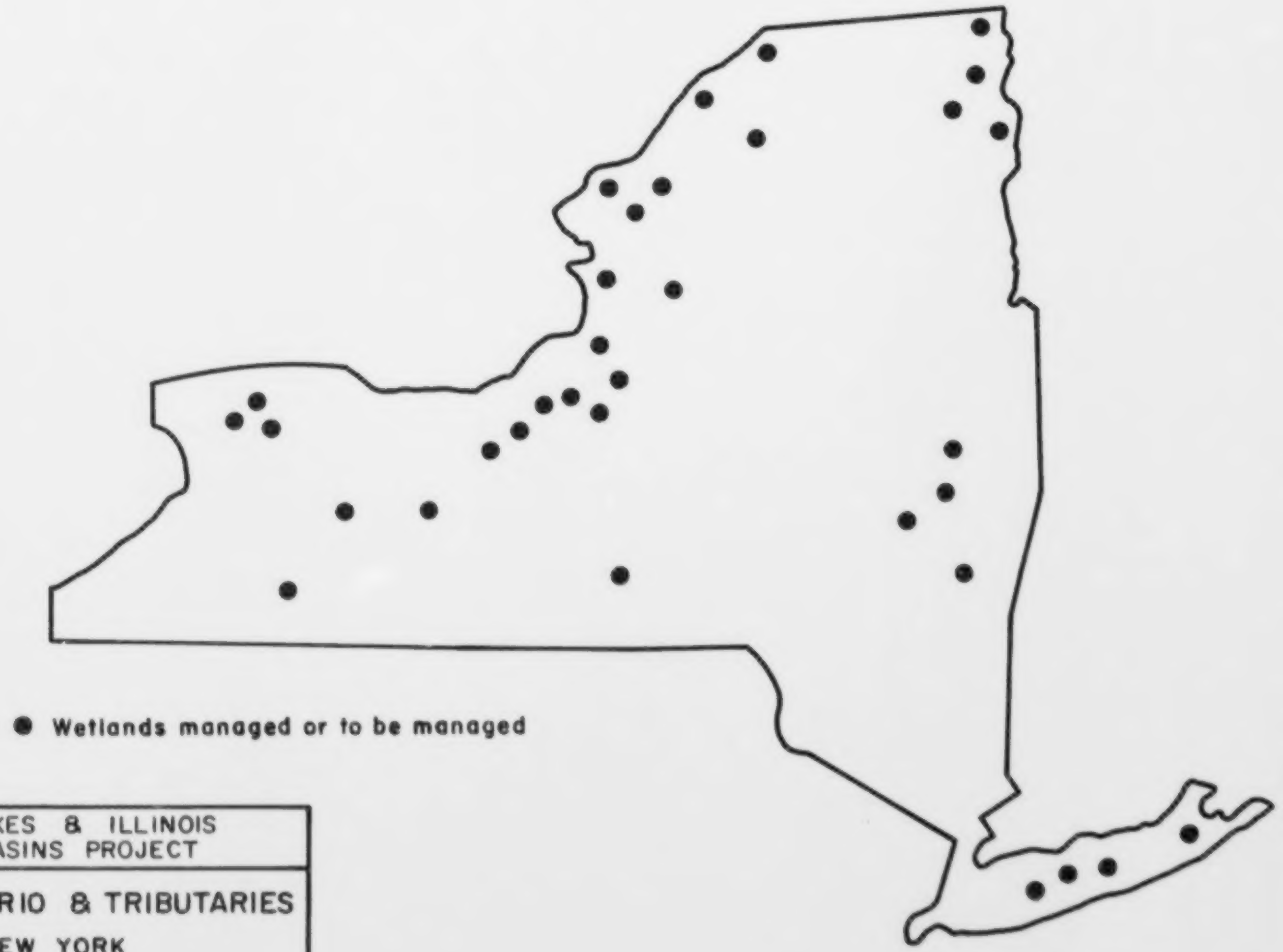
● Wetlands managed or to be managed

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FIGURE 11

consistently been a high duck production area. These marshes are also noted for the exceptionally large muskrats produced there.[23]

Management of wildlife in the Lake Ontario Basin then is based almost entirely on preservation and protection of as many acres of high quality marshlands as is possible.

ECONOMIC ASPECTS

SPORT FISHING AND HUNTING

General.--Application of economics to fishing and hunting involves computation of the monetary outlay of the sportsman, plus an evaluation of the less tangible esthetic and personal values. The 1965 National Survey of Fishing and Hunting provided estimates of the tangible expenditures of freshwater fishermen of the United States at an average of $88.71. This figure includes license, privilege fees, all types of equipment, transportation costs, food and lodging. This figure, together with similar computations for big game and small game hunters, ($63.78 and $58.17, respectively) does not take into account these intangible values which benefit the sportsmen but have no price tag.[24]

The Lake Ontario Basin provides many areas rich in both tangible and esthetic values. The Finger Lakes and several smaller adjacent lakes are recognized for their high value sport fishing and wildlife. The mountainous region of the St. Lawrence Subbasin provides unusually high esthetic values while attracting thousands of sportsmen to the area for hunting and fishing.

Sport Fishing Demand.--Fishing opportunities in the basin are great. Approximately two million surface acres of water in the United States portion of the lake, plus thousands of acres of water in the tributary area, offer fishermen a great variety of fishing opportunities. These include both warmwater and coldwater species. The 1962 report, Sport Fishing Today and Tomorrow, estimated 12 million fisherman days of use for 1960 and for all of the Great Lakes. Estimated use by 1976 was doubled, tripled for the year 2000.[25/]

The estimated total fisherman days expended in 1960 in the Lake Ontario Basin, on the basis of an estimated 2,100,000 basin residents 12 years of age and over, was 3.2 million. Projected fisherman day use by the year 2020, based upon estimates and demographic projections, is 6.4 million. The increase in angling in the basin will depend upon the success of research and management programs for Lake Ontario's extensive fishery and maintenance of satisfactory stocks of fish. Part of the problem is a poorly balanced fishery. The lack of a commercial fishery, healthy and vigorous enough to harvest the low-valued species, has tended to limit production of high-valued species. Until the demands of recently introduced predator species are known, intensive harvest of low-value forage species may not be desirable. In the past, inflexible regulations have contributed to fishery management problems. However, recent legislation in New York has provided for a considerably improved outlook for the future.

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__Hunting Demand__.--Opportunities for hunting in the basin are somewhat restricted by the low percentage of land in public ownership or otherwise open to the sportsman. There is extensive use made of existing areas by the thousands of basin hunters. The hunter day use in the basin is estimated at 1.8 million hunter days for 1960. Projections to 2020 increase this estimate to 4.6 million hunter days per year. This increase in hunting pressure, together with increased ecological pressures on wildlife populations, will call for careful management of existing stocks and habitat.

COMMERCIAL FISHING

__General__.--Economics-related problems of harvesting, processing, and marketing have been growing in recent decades in the Great Lakes commercial fishery, further complicating the basic problems of decline of the high-value species. There is, however, a lack of basic knowledge of the economic structure of the commercial fishery. A similar lack of detailed knowledge exists on changing consumer demand and preferences. Without such information, it is difficult to relate knowledge of the level and stability of supply to costs and efficiency of various harvesting and processing methods and to the demand. With such information, tasks of determining whether unused or underutilized fish stocks can be taken and sold at a profit and pinpointing areas of technological research needed to provide efficiency and encourage market demand, would be greatly facilitated.

The overall problems of the Great Lakes commercial fishery are present in a particularly acute form in the United States waters of Lake Ontario. Decline has been accelerated until only one full-time commercial fishing operation remains along the entire United States shoreline. The situation is somewhat better in Canadian waters, which now produce roughly 90 percent of the total Lake Ontario catch, as may be seen in Table 9.

Table 9.--Average Production and Value for Years of Record, in the Commercial Fisheries of United States and Canadian Waters of Lake Ontario, 1935-1965

(Thousands of Pounds and Dollars)

Period	United States Pounds	United States Value	Canada Pounds	Canada Value	Total Pounds	Total Value
1935-1939	827	65	3,148	216	3,975	281
1940-1949	515	66	2,403	317	2,918	383
1950-1959	297	64	2,160	367	2,457	431
1960-1965	260	51	2,081	345	2,341	396

Harvesting.--Declines in populations of the choicer species and increases of species currently less marketable have put great strain on traditional harvesting methods. Nevertheless, the tendency has been to cling to these traditional methods, even though they have become less and less profitable, in the hope that the highly desirable and valuable species will return to their previous abundance. There has been a lack of capacity to respond to rapidly-changing conditions with flexibility and positive approaches.

Principal existing capital investments are in boats and nets while shore facilities are limited, with consequent necessity for selling fish as landed. Capital reserves are limited or non-existent.[26], [27], [28]

Gill nets and trap nets catch currently abundant species efficiently at times. However, costs of handling large volumes of low-value fish after capture and the sporadic short production periods experienced with these systems, reduce their effectiveness for industrial fisheries operations. Development of versatile fishing operations which will utilize multipurpose vessels, more efficient fishing systems (including trawling), and modern handling methods for fish and fishing gear is necessary. The effectiveness and practicability of trawling was demonstrated in Lake Ontario by one fisherman in the early 1960's. Smelt were taken in commercially significant quantities. A continuing fishery did not develop due to lack of suitable processing and marketing systems.

Processing.--Fishery products are an excellent source, both of balanced animal protein and vital growth factors of significance to human and animal nutrition. Handled carefully and processed properly, they offer desirable variety, as well as an excellent starting material for a spectrum of industrial uses.

Under historical conditions, handling and processing were probably adequate for consumer needs and standards of the times. In comparison with recent advances of other segments of the food industry, however, the commercial fishery has fallen far behind in modernization of plants and processing techniques, development of new and improved food products, and quality control and sanitation programs. These problems are not specific to the Lake Ontario fishery and their eventual solution will have to be on a national, or at least a regional, basis.

In recent years, the Bureau of Commercial Fisheries, with the assistance of university researchers and segments of the industry, has developed promising approaches in processing technology. Experimentation and study have concentrated on (1) means for improving the quality and extending the shelf life of fresh and frozen fish products, (2) greater mechanization of fish processing and handling, (3) development of smaller portable equipment for fish reduction, and (4) the development of quality and sanitation guidelines as a consequence of extensive microbiological research.

The present depressed state of the industry apparently has discouraged investment in new and experimental approaches for improved fish handling and processing. This failure of the commercial fishery to keep abreast of modern processing technology has been compounded by a variety of problems related to environment and environmental change. These include botulism poisoning outbreaks and evidence of build-up of pesticide and insecticide residues in Lake Ontario fish. Studies by the Bureau of Commercial Fisheries indicate residue concentrations in Lake Ontario fish to be lower than Lakes Michigan, Huron, and Erie but higher than Lake Superior.

Marketing.--The Lake Ontario Basin had 2,100,000 people in 1960 and this population is expected to more than double by 2020. When the basin's location with respect to both the populous midwestern and northeastern sections of the United States is also considered, market potential for fishery products is obvious. Despite this potential, the actual economic and marketing situation has been rather static. High costs of production, limited and unstable markets, the disproportionate costs of shipping small lots of fish, especially from remote areas to major city outlets, plus the rising volume of imports of the more desirable species, account for the major marketing difficulties of the Lake Ontario commercial fishery.

In general, the demand for the highly valued species in relatively limited supply has been maintained, while consumption of less desirable species has declined with substitution of inexpensive meat products and the changes in religious practice. At the same time it has been only recently that fresh water species have been processed and distributed in the convenient packaged forms which have characterized marine products since the end of World War II. The marketing of fish to obtain a share of these markets entails a somewhat higher level of mechanization than previously prevailed, plus strict adherence to efficient operations from harvesting through retailing. These qualities have often been lacking in the past in the Great Lakes fisheries.

There have been significant advances in broadening non-food uses of fishery products, including fish meals, fish oils and raw fish for manufacture of pet food and for feeding fur-bearing animals, particularly mink. Translation of these advances into increased demand and consumption for fresh-water fish has not kept pace with the potential, however. Evidence of persistent pesticide residues in some Great Lakes fish has created a major marketing problem. Strict regulations on the sale and use of such pesticides are needed throughout the Great Lakes Basin.

Projected Demand.--The products of the Lake Ontario commercial fishery are largely consumed outside the basin. Therefore, analysis of needs cannot be confined to this basin or even the combined basins of all the Great Lakes. Dependence must be placed largely on national statistics and trends, combined with regional production figures.

Based on these factors, future demand for fishery products from the Great Lakes has been projected to the year 2020 (Table 10).

Table 10. Projected Demand for Fishery Products from the Great Lakes
(millions of pounds)

Year	Total Demand (Edible and Industrial Products)
1960	104.7
1980	147.0
2000	228.0
2010	303.0
2020	412.5

The projections assume a medium population growth, a medium per capita disposable personal income, and an income elasticity of demand for edible fishery products of 0.32. Thus, consumption of edible fishery products is expected to increase on a per capita basis with the rise in disposable income. It is believed that effects of increasing income in the future on consumption of fish will not be offset to the extent they have been in the recent past by other factors, such as declining prices and increasing supplies of poultry, beef and other animal proteins. Also, programs now under way or being considered in the areas of product development, improved marketing and handling, and consumer education are likely in themselves to result in an increase in demand. Projections of consumption of industrial fishery products are also included in the figures for total demand and are based largely on increases in broiler production, since the bulk of fish meal is consumed in that industry.

During the period 1960-1964, domestic Lake Ontario landings represented only about .5 percent of United States Great Lakes landings, although combined U. S. and Canadian landings from Lake Ontario averaged 2 percent of total Great Lakes landings (Table 11). Projected demand for commercial fishery products from the U. S. Great Lakes indicates almost a fourfold increase over 1964 levels by the year 2020. A proportionate increase in Lake Ontario landings to meet projected demand would entail annual production of approximately 1.25-1.5 million pounds by 2020. Overall, however, future demand for fish produced in the Great Lakes appears sufficient to induce a considerably higher utilization of the Lake Ontario resource base. To meet this need, there is an obvious requirement for study and implementation of all reasonable means (including applicable water quality control) to preserve and enhance the commercial fishery resource.

Table 11. Proportion of Great Lakes Commercial Fishery Production (Thousands of Pounds) Supplied by Lake Ontario (U. S. and U. S.-Canada Combined)

Year	U. S. Great Lakes	U. S. Ontario	%	All Great Lakes	All Ontario	
1960	65,936	258	--	104,722	1,958	
1961	67,140	351	--	113,384	2,460	
1962	61,850	233	--	116,413	1,981	
1963	55,823	233	--	99,598	2,008	
1964	53,559	267	--	87,604	2,282	
Ave.	60,861	268	.44	104,344	2,138	2.0

WATER QUALITY ASPECTS

GENERAL

"Water quality", in a very broad sense, includes not only those items commonly recognized as directly affecting human well-being, but also the entire complex of environmental factors influencing waters. It is within this framework that fish and wildlife science and management can make unique contributions to the identification and solution of water quality problems. Some water quality factors, such as color and pH, of direct importance to human and industrial uses, can be relatively inconsequential to many fish and aquatic organisms. Other factors can effect subtle and intermittent changes in water quality that will be detrimental to fish and aquatic organisms long before gross, easily-measurable, and plainly observable effects begin to disturb human beings.

Sources specifically damaging to fish and wildlife include cannery wastes, pulp mill effluents, herbicides, pesticides, industrial and municipal wastes, and oil spills. In some instances, thermal effects cause problems. Table 12 shows primary sources of pollution in the major tributary streams. Smaller tributaries within each of the larger tributary systems are included.

Expanding populations, industrial developments, and the increased use of pesticides are constantly adding to the great volume of pollutants now being discharged to basin waters. Locally, increased fertility is responsible for heavy demands for oxygen by decomposing plant and animal matter. This, in turn, creates adverse conditions for many species of aquatic life.

Table 12. Primary Sources of Pollution of Some Lake Ontario Watersheds

	Sources of Pollution											
Watershed	1	2	3	4	5	6	7	8	9	10	11	12
Eighteen Mile Cr.	*	*		*		*	*	*	*	*	*	
Barge Canal	*	*		*		*				*		*
Lower Genesee R.				*		*						
Upper Genesee R.	*	*	*	*		*					*	*
Oswego R.	*	*	*	*		*						*
Seneca R.	*	*	*			*				*		
Oneida R.	*	*		*		*						
Black R.		*		*	*	*			*		*	

1. Cannery Wastes
2. Milk Processing Wastes
3. Metal Plating
4. Various Industrial
5. Paper Mills
6. Sewage
7. Phenol
8. Plastics
9. Automotive parts-oils
10. Various chemicals
11. Gravel pit washings
12. Agricultural wastes

Fish.--Pollution does not always directly result in fish kills, but the food chain and environmental conditions may be so changed that indirect losses occur. Fish nesting sites and spawning areas, for example, are vulnerable to pollution from pulp, cannery wastes, and other pollutants.

Table 13 shows that spawning can occur at almost any season of the year. This is one reason why pollution is objectionable at any

Table 13. Spawning Information of Common Fish Species, Lake Ontario Basin

Species	Time	Temperature	Area	Method
Muskellunge	Late April through mid-June	48-56°	Weedy Bays	Broadcast
Northern Pike	March through May	40-46	Shallow marshes	Broadcast
Walleye	March through June	45-50	Rocky shores	Broadcast
Yellow perch	April through June	48-56	Weeds, stumps	Jelly bands
Crappies	May through early July	40-80	Gravel bottom	Nest
Channel catfish	Mid-April through early July	65-75	Swift water	Nest
Carp	April through July	80-90	Shallow marshes	Broadcast
Smallmouth bass	May through early July	62-65	Gravel rock bottom	Nest
Largemouth bass	May through early July	62-65	Gravel rock 2'-6'	Nest
Sunfish sp.	May through early September	65-80	Gravel rock 2'-6'	Nest
Rainbow trout	Mid-February through late May	55-65	Gravel bottom	Nest
Brown trout	October through early December	45-55	Gravel bottom	Nest
Brook trout	Late September through early December	45-55	Gravel bottom	Nest
Lake trout	Late September through early December	40-50	Gravel bottom	Nest
White bass	April through early June	58-75	Rocky shore	Broadcast
Smelt	March through Mid-May	40-50	Gravel bottom	Broadcast
Alewife	Mid-March through June	55-60	In streams	Broadcast

time. Not only can pollution destroy the nest site or prevent its being built, but it can seriously degrade water quality, thus inhibiting fish production by exerting various biological, chemical and physical checks.

Fish species have been categorized in Table 14 according to their tolerance to pollution. The term "facultative" refers to game fish species that can exist under varying conditions. Tables indicating minimum and desirable dissolved oxygen requirements for the three tolerance categories are available. However, water can have a diversity of quality conditions even though dissolved oxygen contents are similar. The synergistic effects of other water conditions or contaminants often preclude the usefulness of such tables.

Wildlife.--Pollution from domestic and industrial sources reduces duck production and destroys or limits the quality of hunting grounds. Oil wastes from commercial vessels and tank storage dumps have an immediate as well as a long range effect on waterfowl and their habitat. Rapid runoff from urban development and poorly managed farmlands causes increased turbidity in many streams. Significant losses of aquatic plants of value to waterfowl have resulted from cases where turbid water conditions have become severe.

Table 14. Categories of Fishes with Similar Water Quality Requirements

Tolerant Fish (Group 1)

- Carp
- Goldfish
- Orange-spotted sunfish
- Suckers
- Gar
- Buffalo
- Catfish
- Bullheads

Facultative Fish (Group 2)

- Walleye
- Northern pike
- Largemouth bass
- Smallmouth bass
- Bluegill
- Fathead minnow
- Yellow perch
- Black crappie
- White crappie
- Shiners
- Muskellunge
- Pickerel

Intolerant Fish (Group 3)

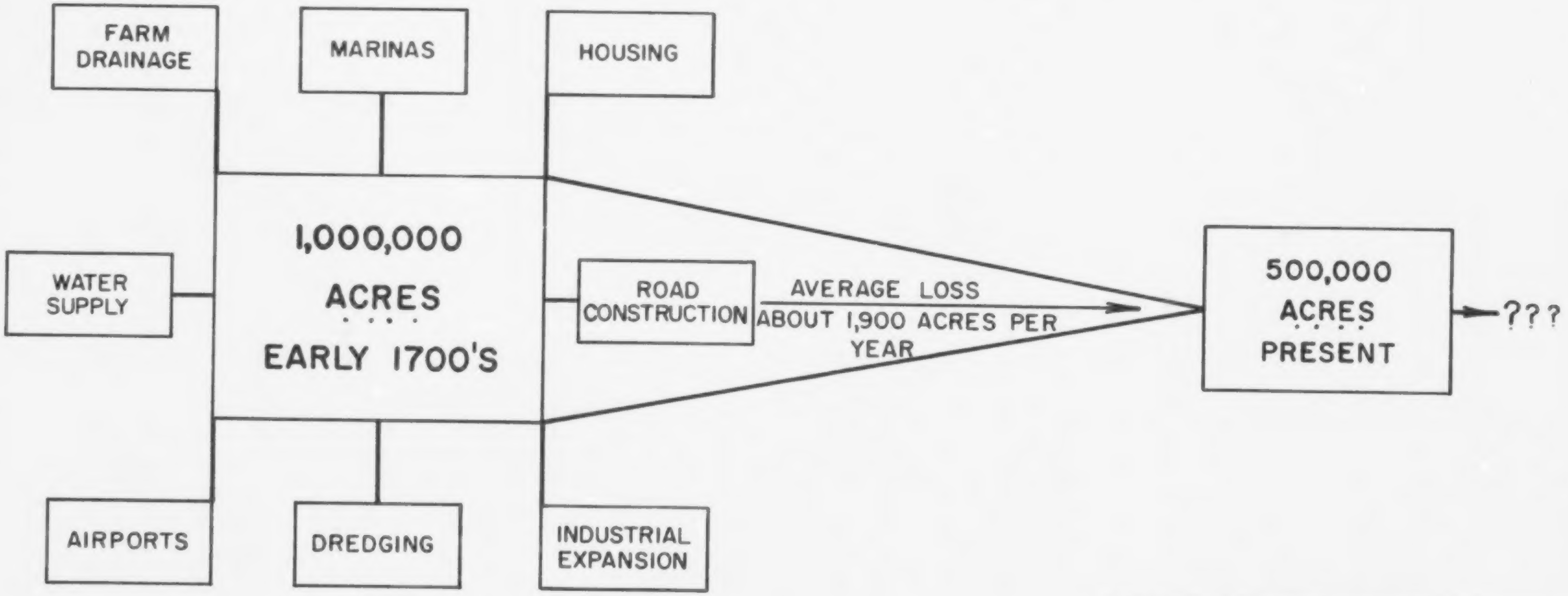
- Rainbow trout
- Brook trout
- Brown trout
- Lake trout
- Stickleback
- Smelt
- Whitefish

In addition to these problems, thousands of acres of New York's marshlands have been lost through road construction, fills for home construction, farm drainage, and various dredging ventures (Figure 12). As a result, irreplaceable lands, needed by aquatic species of birds and mammals, have been lost forever.

LAKE ONTARIO

Open Waters.--Water quality in Lake Ontario has not reached that critical stage which characterizes Lake Erie, but local problems forecast major problems in future years. Fish and other aquatic resources of Lake Ontario will indicate environmental changes occurring, their magnitude and rate of change, and possible solutions. To understand what is happening in the open waters of Lake Ontario in terms of water quality effects and trends, we need only recognize that the bulk of the water in Lake Ontario has already passed through Lake Erie.

There is one important respect in which the above parallelism in water quality trends between Lakes Erie and Ontario does not hold true. This concerns suspended solids and organic material. Huge quantities of solid pollutants are carried into western Lake Erie by the Detroit and Maumee Rivers and other smaller tributaries. Gradual settling of these pollutants occurs over Lake Erie's western and central basins. With Lake Erie functioning as a vast settling basin, its outflowing waters are largely devoid of suspended solids and organic matter, but these waters remain relatively high in


FARM DRAINAGE
MARINAS
HOUSING
WATER SUPPLY
1,000,000 ACRES EARLY 1700'S
ROAD CONSTRUCTION
AVERAGE LOSS ABOUT 1,900 ACRES PER YEAR
500,000 ACRES PRESENT
???
AIRPORTS
DREDGING
INDUSTRIAL EXPANSION

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE ONTARIO & TRIBUTARIES

LOSS OF MARSHLANDS IN NEW YORK

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 12

dissolved materials. Allowing for oversimplification, we may say that the water chemistry in the eastern end of Lake Erie is very similar to what we start with at the western end of Lake Ontario.

Limited studies of Lake Ontario suggest excellent oxygen conditions, except for several stations in the eastern end of the lake, particularly off the mouth of the Bay of Quinte. These conditions are apparently associated with local pollution concentrations in the bay area, together with effects from the International Rapids installations in the St. Lawrence River. On the basis of this limited sampling, it is concluded that dissolved oxygen concentrations in most of Lake Ontario are optimum or nearly so at all times for fish life. Except for the scattered occurrences noted above, there is little evidence of any overall worsening of dissolved oxygen levels in the main lake. Likewise, sampling of bottom organisms in the lake reveals uniformly good populations of pollution-intolerant forms such as amphipods, mayfly nymphs, and caddisfly larvae. These are reliable biological indicators of good water quality. In summary, the open waters of Lake Ontario have been little affected by pollution to date.

Although fish populations have fluctuated widely, as reflected in past records of commercial harvest, there is little correlation evident between these fluctuations and environmental changes. Such correlations may exist, but data are inadequate to permit such relationships to be demonstrated. The gradual enrichment of both Lake Michigan and Lake Erie environments was responsible for temporary upsurges of fisheries productivity, followed by decline. There is no evidence that such a response has occurred in Lake Ontario fish populations.

Shore Waters.--The water quality degradations occurring in the Lake Ontario Basin have tended to remain concentrated in the tributaries, inland lakes, and certain inshore areas. Opportunities to enjoy water sports such as swimming and water skiing have been curtailed in these areas by high bacterial counts, by odoriferous dead plants and fish, and by other unsightly debris in the water and on the beaches. The New York State Health Department examined five areas of Lake Ontario during 1957 to determine the extent of shoreline pollution.[4/] In brief, the following results were obtained:

Shore Waters in the Vicinity of Oswego Harbor. Water is polluted by untreated discharges of sewage and papermaking effluents. B.O.D. values and M.P.N. values were high. D.O. concentrations were over 70 percent of saturation. Color and turbidity changes were rather marked. Greenish turbidity resulted over a wide area, following periods of north winds. Westerlies carried the contaminants substantial distances along the shore. Suspended solids and settled materials were observable along shore areas and well into the lake.

Oswego Harbor to Genesee Mouth. The lakeshore waters were adversely affected by pollution entering the lake from Oswego River, and raw sewage discharged along Oswego Harbor. There was heavy pollution from domestic sources and coliform bacterial counts were high. Chloride concentrations of polluted river water were commonly up to 10 times normal values. Effects of this pollution extended outward from the harbor entrance for about a mile.

Genesee River to Braddock Point. There was serious shoreline pollution in this area. Genesee River and Irondequoit Bay effluents, both domestic and industrial, contaminated these waters.[29] The Rochester sewage treatment plant was contributing substantial loads. Algal growths created problems. Brown turbid discoloration was characteristic. Several square miles were affected along the outer periphery of the polluted area, with dense algal growths commonly occurring in this zone. Except for an area along the mouth of the Genesee River, where oxygen levels are generally low, the inshore and bay waters were often supersaturated, possibly because of the prolific algal growths. Bathing beach waters in the vicinity of Rochester carried significant bacterial pollution, including coliform. Mill Creek, Genesee River, and Rochester sources contributed substantially to the problem. Fortunately the effects were rather local and were rapidly dissipated in the lake.

Braddock Point to Eighteen Mile Creek. Water quality in this area was degraded locally by pollution from tributary streams. B.O.D. concentrations were generally low, except at the mouth of some of the streams. Johnson Creek turbidities and pollution loads were occasionally severe. Water quality of the beaches in this area generally reflected the problems of local pollution, with varying pollution loads contributed along these inshore areas by the tributaries.

Eighteen Mile Creek to Niagara River. Chemical analysis of samples collected from the lake in this area did not indicate excessive pollution. Oxygen levels were high and B.O.D. concentrations low. Coliform densities represented some pollution, as measured by bacterial analysis. The high M.P.N. values found east of the International Boundary line suggested the entrance of additional bacterial pollution from west of the Boundary line, indicating sewage contamination of the area between Eighteen Mile Creek and Niagara River.[30]

Recent surveys of these same general areas by the Federal Water Pollution Control Administration revealed grossly polluted conditions in numerous instances.[1] This indicates further lowering of water quality in the few years between the studies. Shoreline fish habitat in the vicinity of Rochester Harbor and Irondequoit Bay have been degraded by domestic and industrial wastes and the resultant effects of over-fertilization. Heavy algal growths and large deposits of decaying organic material add to the problem, especially in Irondequoit Bay.

Fish kills had occurred at a rate of one or more per year for a 15-year period.[31] At least one kill was caused by cyanide.

Other toxic materials implicated in the kills were chlorine, metal plating wastes, copper and iron salts, and oil. Effects of this pollution are undoubtedly felt downstream to the mouth of the Niagara River, where it enters Lake Ontario.

The pollution of estuaries and inlets that serve as spawning and nursery grounds for fish and nesting and resting areas for waterfowl is cause for considerable concern. Where pollution occurs primarily near river mouths, food chains are disrupted or destroyed, causing stress to wildlife populations. Oil on the surface of the water has been cited many times as a direct cause of waterfowl losses. Oil spills from many sources are reported each year. Often these spills are blown into shore areas where adverse effects occur to various forms of wildlife.

Inland Lakes.--With the exception of Lake Onondaga, inland lakes in the basin have acceptable habitat for fish populations. Although over-fertilization is becoming a problem, water quality is good for fish life. Lake Onondaga presents the most acute pollution problem in the basin. Aquatic life and habitat have been greatly affected. The tullibee, a deep-water species, has completely disappeared from the lake fauna. Deep water areas are unsatisfactory for any form of aquatic life. Carp, a tolerant species, exhibits poor growth in a progressively worsening environment. Accumulation of sludge and carbonate deposits are such that improvements of the aquatic habitat would be extremely slow, if possible at all.

SUBBASINS

Niagara River.--The tributaries from the United States side of the Niagara River have long histories of heavy domestic and industrial pollution, with subsequent oxygen depletion of the tributary water. Buffalo, Tonawanda, and Niagara Falls, New York, are sources of waste dumped directly into the Niagara River. Large amounts of industrial wastes discharged into the river often cause obnoxious odors to residents living near the river mouth. Oil wastes from bilges have severely degraded some shore habitat, particularly in smaller bays.

In the 1948-49 season, about 700 waterfowl were swept over Niagara Falls and killed. Of this number, it was estimated that 275 died as a direct result of oil pollution.[1] A 1951 report on pollution of the lower Niagara River further substantiated waterfowl losses due to oil pollution.[31]

Losses of waterfowl which can be attributed to oil are increasing, and substantial numbers of oil-soaked ducks appear below Niagara Falls each winter. Heaviest mortalities occur from early November to May. There is special concern for the diving ducks along the eastern end of Lake Ontario, where ocean vessels discharge their wastes. This area is an important resting area for migrating waterfowl. Extensive kills of waterfowl have resulted from oil tanker spills or from bilge pumping.

In 1960, New York Conservation Department personnel obtained records of about 3,000 ducks taken by hunters. Of these, 265 were contaminated by oil. Although able to fly, many ducks were heavily oiled. Other surveys that year showed that 23 of 195 ducks taken from the Lower Niagara River had oil on their feathers when trapped for banding. An additional 11 ducks were found dead from the effects of oil after they had been banded.

Industrial discharges entering the Niagara River have primarily killed minnows, but northern pike, largemouth bass, sunfish, and crayfish were also lost. These toxic wastes were from an automobile manufacturer, a paper company, and a metal plating firm.

Genesee River.--The lower section of the Genesee River is polluted by industrial wastes and storm drain discharges containing raw sewage.[29/] The frequent absence of dissolved oxygen, plus the progressive deterioration of bottom conditions, has seriously reduced the value of fish habitat in this section of the river. In 1951 and 1965, studies of the Genesee River showed areas of significant pollution in the downstream section of the river. The main stem of the Genesee in the vicinity of Rochester had such poor water quality that fish habitat was destroyed. In the lower sections of the river, oxygen sag during periods of low flow limited fish life and occasionally fish kills have occurred.

The flood plains of the Genesee River were extensively used by waterfowl during spring migrations. Presently, this use has been almost eliminated due to urbanization of the flood plain and the construction of flood control projects. A few wooded swamps around some inland lakes in the basin have good water quality and habitat heavily used by aquatic animals.

Oswego River.--There is heavy fishing pressure in the headwaters and some of the upper tributaries of the Oswego River, but sections of the lower reaches are not suitable for fishing. The organic waste load often reduces the dissolved oxygen to critical levels for aquatic life.

Extensive fish kills occurred below Waterloo and Seneca Falls in October 1961, September 1962, and October 1967. Causative agents were reported to be partially treated municipal and cannery wastes. Deoxygenation of this section of the river has occurred at times to such an extent that the D.O. was reduced to 1 to 2 mg/l below Seneca Falls.

The Owasco Inlet, which is badly polluted, discharges polluted water into Owasco Lake.

Surveys of duck losses in the Finger Lakes area showed that oil pollution was partially responsible for bird mortalities. Where birds died of apparent starvation, oil was believed to be a contributing factor.

Black River.--A 1931 biological survey of the Oswegatchie and Black River Basins revealed 73 miles of polluted stream.[32/] Black River pollution problems are severe. The greatest waste problems are centered around towns along the Black River where paper mills flourish. Other wastes emanate from milk plants and untreated sewage. Portions of Black River Bay were polluted from contaminated stream discharges. Generally, pollutants in the Black River Watershed included: pulp, dyes, sewage, milk wastes, sulphites, excelsior, and cannery wastes.

Sampling of sections of the Black River in 1965 did not indicate that stream conditions had improved. On the contrary, evidence was strong that stream conditions had deteriorated further since the 1931 study. Extreme fluctuations in flows of the Black River, together with heavy loading of wastes, cause wide ranges in dissolved oxygen. Low levels of dissolved oxygen in the river below Watertown, New York, have created adverse conditions for fish life. Downstream from Lyon Falls, poor water quality has caused damage to warm-water fish and reduced their numbers in some sections.

St. Lawrence River.--The water quality in the St. Lawrence River is generally good, presenting few problems to the aquatic inhabitants.

FUTURE REQUIREMENTS

MANAGEMENT-ORIENTED

General.--In order to obtain maximum benefits from management of fishery resources of Lake Ontario, an integration of biological and economic objectives will be required. In the management of a fishery, the role of the biologist is to provide information of biological potential. The task of the economist is to determine the level of fishing effort within the biological potential that will produce the maximum economic return. Effective management necessitates a joint effort. While this future management must be considered within the context of the overall Great Lakes fishery, the particular characteristics of the Lake Ontario situation require special adaptations of overall Great Lakes management policies and objectives.

Regulatory Program.--This is a complex and controversial area and its past and present problems have already been described. Unlike the other Great Lakes, Lake Ontario is subject to only two jurisdictions - New York and Ontario, thus simplifying many of the problems. Nevertheless, there is a requirement for closer coordination and cooperation if discrepancies and overlapping are to be avoided. The mechanism for such cooperation and coordination in fishing matters already exists within the Great Lakes Fishery Commission structure, particularly in its Lake Ontario committee. Positive contributions can also be made by the Great Lakes Commission, the International Joint Commission, and the Great Lakes Basin Commission.

The traditional orientation of the commercial fishing regulatory structure has been towards legislating inefficient gear, in order to prevent depletion of stocks. The standard approach has been toward restriction in size or number of some types of gear and the total prohibition of others. Attempts to foster fishing methods geared to efficient and economic harvesting of abundant, low-priced fish has often been penalized by the regulatory structure. There is obviously a need for sounder, more flexible regulations, thoroughly coordinated between the two jurisdictions involved. Regulations, however, cannot be effectively considered apart from the concept of limited entry and allocation of stocks.

In the past, exploitation of a common property resource like the Great Lakes fishery has been characterized by a flow of fishermen into and out of the industry, depending on the abundance of various species and prevailing prices. Freedom of entry has tended to reduce the profits that a fixed number of fishermen could have made during periods of favorable prices and abundance, thereby reducing available reserves during depressed periods. One of the results of this situation has been the financial inability of many fishermen to undertake the changes or modernization needed to adjust to changing conditions. An over-allocation of resources in the fishery frequently occurs as well. It seems clear that in the case of some species there has been depletion of stocks, caused by over-concentration of fishing effort. Therefore, reasonable restriction of the number of commercial fishing operators on public waters (limited entry) must come if the economic objective of developing a healthy and profitable commercial fishery is to be achieved. In Lake Ontario, the organization of the Canadian commercial fishery has many of the attributes of a limited entry fishery. Existence of only one full-time commercial fishing enterprise in United States waters of Lake Ontario may be viewed as an unplanned facsimile of limited entry conditions. It is recognized that an efficient, planned program of limited entry poses many complex problems of data collection and management. Over the long run, however, a flexible, and equitable system of limited entry, managed on a lake-wide basis, would greatly enhance the efficiency and viability of the commercial fishing industry.

By definition, limited entry is purely an economic tool designed to result in a profitable, efficient fishing industry. Management of Lake Ontario fish stocks must be approached from a broader perspective that considers all legitimate users of the resource. Any allocation of stocks will be seriously hampered by the wide fluctuations in abundance of most Lake Ontario species.

A sound commercial fishery regulatory program must likewise be coordinated with related regulatory programs such as those for sport fishing and water quality (pollution) control where interests overlap. Little of this has been done in the past and it is questionable whether sufficient reliable knowledge has been available to serve as a basis for effective coordination. For the future, however, such coordination is a definite requirement and should be implemented through the existing mechanisms cited above.

Biological Program.--This involves research and management of both the fish stocks and the habitat that supports them. Due to the close relationship of the latter to water quality considerations, it will be covered in the report section dealing with water quality requirements. This section will concern itself primarily with research program requirements of the fish stocks. It should be constantly remembered, however, that this is essentially an artificial division. The fisheries of Lake Ontario and their environment are both parts of an interacting whole, with drastic population shifts, water level changes, and pollution effects occurring simultaneously.

Future advances in biological knowledge and management techniques may permit direct manipulation of fish stocks. Indeed, some direct management tools such as sea lamprey control and introduction of new species are currently in use. Lake Ontario is the last of the Great Lakes scheduled for treatment under the sea lamprey control program and intensive survey work on tributary streams has not been undertaken, although some preliminary inventories have been made. Past experience with introduction of exotics into the Great Lakes system indicates the need for great prudence and proper safeguards in this approach. However, restriction of such introductions to salmonids (trout and salmon) holds the risks to acceptable proportions. On this premise, New York has begun a coho salmon introduction program with eggs obtained from Michigan, while Ontario has introduced the kokanee salmon and splake trout. Attempts to re-establish lake trout have not been successful to date. The extent to which stocking of salmonid predators will affect Lake Ontario's fishery is not clear. It is apparent, however, that there will be substantial research requirements for monitoring and evaluating these stocking endeavors, in order that data may be available to serve as a basis for future management decisions.

There is a similar need for better information in the area of indirect management; that is, prediction of abundance and distribution of various species to permit advance adjustment by the commercial and sport fisheries and management agencies. This need is of utmost importance under conditions of limited entry management.

Against this overall management background, a biological program specifically geared to Lake Ontario should give particular attention to the following areas:

1. Statistical compilations. The present method of collecting and summarizing data on the catch and effort of the commercial fishery has proven satisfactory and should be continued. The system should, however, be kept under continual review to assure sound interpretation and adequacy of procedure as fish stocks and fishing methods change. Particular attention must be given

to the possible influence of gear modifications, fishing regulations, and economic factors on the statistics.

Knowledge of the amount of the sport fishery production is becoming increasingly important for the sound management of the fishery. Recent estimates indicate that the annual catch of some species by anglers may exceed several million pounds and that the sport fishery is a major user of the resource in certain areas. Data on the sport fishery and the commercial catch statistics will provide figures not previously available on the total production of the lakes. The field checking of statistical sampling of the sport fishery may be coordinated with the collection of biological information on the sport catch, or carried out as a joint project.

2. Monitoring fish stocks. The systematic collection and analysis of information on the abundance and biological characteristics of fish stocks is vital to the indirect management approach outlined above. Continuous sampling is necessary to keep abreast of the constantly changing structure of fish stocks, particularly the lightly-fished species. Representative samples and accompanying relevant information should be collected with due regard to the adequacy of information provided by the commercial and sport fisheries.

Information on the relative abundance, growth, and survival of the young of principal species, obtained by systematic sampling, will make it possible to forecast their abundance when they eventually enter the fishery. This knowledge would be of practical value to the industry in preparing markets and readying appropriate fishing gear and to agencies responsible for managing or carrying out investigations of the fishery.

3. Delineation and assessment of populations. The foregoing investigations indicate the importance of information of the "total" fish population of Lake Ontario. However, there is evidence that some species may form sub-populations which differ from one another in their growth, mortality rates, movements, behavior, and other life history features. These differences must be taken into account in managing the fishery. Tagging and/or marking programs will be required to provide the necessary information. The causes and magnitude of shifts in fish population dynamics should be determined. Such investigations should give attention to the factors responsible for significant sub-lethal effects on fish as well as those which cause obvious mortalities.

4. Physiology and behavior. This work should provide information of optimum ranges and lethal limits of temperature and oxygen, and the metabolic rates under both optimum and sub-optimum conditions. The behavioral responses to physical features of the environment such as light, current, temperature, and chemicals, as well as responses to biological features such as food, associated species dominance relationships, and spawning stimuli should be determined.

The relationship of these physiological and behavioral investigations to the water quality considerations that are the chief concern of the Federal Water Pollution Control Administration is a very close one. They should be supplemented by direct work on the effects of domestic, agricultural and industrial wastes on fish and fish-food organisms. Studies should include both existing and anticipated wastes and tests should be made of each constituent of the wastes, both separately and in combinations. The influence of wastes on fish should include studies of all life-history stages, with particular attention to critical stages such as incubation, hatching, and early life.

The practical end point of this research will be the development of reliable and workable water quality criteria and standards for fish and aquatic organisms for a large number of parameters under natural conditions.

Beyond a few fairly well-established items, very little is known of what workable aquatic life water quality criteria are necessary under non-laboratory conditions, particularly when combined or synergistic situations are involved. Most of New York State's water quality standards have been approved by the Secretary of the Interior under the provisions of the Water Quality Act of 1965. These determinations had to be made in spite of the lack of information. Detailed implementation and assessment of these standards, as well as possible future revision, will require more adequate data.

5. Environmental and limnological studies. Lake Ontario does not exhibit the severe environmental changes that have characterized the situation in Lake Erie. There is little question, however, the change has taken place. Very little is known of the inter-relationships of these changes with the dynamics of fish populations. Study needs are spelled out in greater detail in the section on "Water Quality Requirements" because of the close relationship of these environmental and limnological aspects to water quality.

6. Commercial fishing at inland lakes. There are many economic and administrative aspects to this possibility but the primary research and management requirements involve biological determinations. Successful solution of the economic problems of the Lake Ontario commercial fishery would tend to carry a potential inland lake fishery along with it. On the other hand, the management implications of commercial fishing as part of balanced utilization of the total fishery resource in at least some of the more fertile inland lakes warrants serious study and consideration. A major public information program will be needed to make commercial fishing acceptable to the sport fishermen and to the general boating public.

Summary

Resolution of management problems of the Lake Ontario fishery will require a much greater degree of joint action and coordination between the jurisdiction and interests involved than has been the case. The existing Great Lakes Fishery Commission, especially its Lake Ontario Committee, offers a mechanism for joint consideration of problems and concerted action. Considerable progress has been made, but much more utilization and strengthening of this mechanism will be required if the various management tools which have been discussed are to be implemented at the necessary level and scope.

Some work is already under way in almost all of the areas of research requirements outlined above, either under the auspices of the Bureau of Commercial Fisheries, New York State and Canadian fish and wildlife agencies, or university staffs, but is limited in terms of funding and manpower. An encouraging development was established in 1964 of the Cape Vincent Fisheries Research Station by the New York State Conservation Department, aided by funding under the Commercial Fisheries Research and Development Act (P. L. 88-309) and the Anadromous Fish Act (P. L. 89-304). Plans are under way by the Conservation Department to construct a 60-foot fisheries research vessel to operate out of the Cape Vincent station.

WATER QUALITY

General

"Water quality" is to be understood in a very broad sense, including not only those items commonly recognized as directly affecting human well-being, but also the entire complex of environmental factors influencing the Lake Ontario fishery. This includes bottom sediments, benthic organisms, and plankton. It is within this framework that fishery science and management can make a unique contribution to identification and solution of water quality problems.

The effects of subtle, sometimes intermittent, changes in water quality are felt by fish and aquatic organisms long before gross, easily-measurable, and plainly-observable effects begin to disturb human affairs. Early investment in studies, and search for solutions of water-quality-related fishery problems has a potential for containing and remedying problems before they reach proportions that constitute a threat to human beings and their activities.

Failure to heed early warnings by fishery scientists of the Bureau of Commercial Fisheries and their associates that major adverse environmental changes were taking place in neighboring Lake Erie, led to costly delays in recognition of the scope of the problem and consideration of remedial measures. The situation in Lake Ontario has not reached the critical stage characterizing the Lake Erie environment, although some indications of trouble are apparent. The opportunity exists, therefore, to utilize the fish and aquatic resources as indicators and guides to not only determine the changes taking place in Lake Ontario--their magnitude and direction--but to point the way to solution.

Such obvious water quality degradation as has taken place in the Lake Ontario Basin has tended to be concentrated in the tributaries, inland lakes and inshore areas. Cladophora, a filamentous algae that normally indicates a rapid increase of aquatic enrichment, has relatively recently become extremely common along both the United States and Canadian shorelines. Opportunities to enjoy water sports, such as swimming and water skiing, have been curtailed in these areas by high bacterial counts and odorous, unsightly dead plants, fish and debris on beaches.

Long-Range Trends in Water Quality

To understand what has happened in the open waters of Lake Ontario in terms of water quality effects and trends, one must turn to the fish and aquatic organisms.

From this standpoint, there is no question that the open water habitat has changed. The bulk of the water in Lake Ontario has already passed through Lake Erie, thus insuring that changed water quality in that lake is passed along to Lake Ontario. Figure 8 shows the changes in concentrations of total dissolved solids of Lake Ontario waters almost exactly paralleling the Lake Erie changes, except that the concentrations are slightly higher. This slightly higher level reflects the additional inputs brought into the lake by its own drainage, including additional inputs of pollution. As in Lake Erie, the changes were gradual until approximately 1910, after which the rate of change accelerated.

Total dissolved solids have risen by almost 50 ppm over the last 50 years. Increases of approximately 6, 16, 5, and 14 ppm have taken place in calcium, chloride, sodium-plus-potassium and sulphate, respectively, with corresponding annual rates of change during the same period of 0.12 ppm/yr., 0.32 ppm/yr., 0.10 ppm/yr., and 0.28 ppm/yr. In themselves, existing or even projected concentrations of these substances are unlikely to directly affect fish and aquatic organisms adversely. However, there is a clear indication that changes are occurring, plus a strong inference of buildup of many other substances for which good, long-range data are not available. Recent accumulations of toxic substances such as pesticides and detergents pose a real threat to the future well-being of fish and aquatic life. Long-range data are incomplete for the critical items of nitrogen and phosphorus, but it is evident that concentrations of these items have increased. Concentrations of these and many other substances may reasonably be expected to continue increasing, perhaps at even a more accelerated rate.

Too little is known of the possible accumulation of such toxic substances as pesticides, detergents, heavy metals, and other chemicals in the waters and sediments and in fish and fish-food organisms. However, recent analyses of pesticide concentrations in Lake Ontario fish by Bureau of Commercial Fisheries scientists show averages of total DDT (DDT, DDD, DDE) of 2.0 ppm for alewives, 2.1 ppm for yellow perch, 2.3 ppm for sculpin, 1.6 ppm for smelt, 5.0 ppm for whitefish, and 4.3 ppm for white perch. Concentrations of dieldrin in Lake Ontario fish were .06 ppm for alewives, .05 ppm for yellow perch, .10 ppm for smelt, .49 ppm for whitefish, and .10 ppm for white perch. These analyses are based on limited samples and additional work needs to be done. The significant point, however, is that we are dealing with parts per million in the fish which have been concentrated from parts per trillion in the water.

Preliminary investigations indicate that the concentrations of these chemicals in Lake Ontario fish are approximately one-half to one-third lower than for the same species in Lake Michigan and slightly higher than occurs in Lake Huron fish. Lake Ontario concentrations are much higher than those in Lake Erie fish. Various buffering factors, including high productivity and high content of organic matter, may account for the low concentrations found in Lake Erie fish. This indicates that pesticide concentrations in Lake Ontario fish are primarily the result of inputs from the Lake Ontario Basin, rather than a carry-over of Lake Erie conditions, as exemplified by concentrations of dissolved solids.

In addition to the differences between Lakes Erie and Ontario in regard to pesticides, there are two other items wherein the prevailing parallelism in water quality trends between the two lakes does not hold true. These are suspended solids and organic material. Huge quantities of these pollutants are carried into western Lake Erie by the Detroit and Maumee Rivers and other tributaries--followed by gradual distribution farther and farther over the bottom sediments of the western and central basins. The key role played by these sediments in the complex interactions that result in widespread oxygen depletion has been described in detail in the Lake Erie report. Thus, although the outflowing waters of Lake Erie are relatively high in dissolved material by functioning as a vast settling basin, Lake Erie's outflowing waters are largely devoid of suspended solids and organic matter. Allowing for oversimplification, we may say that the aquatic environment present in the eastern end of Lake Erie is what we start with at the western end of Lake Ontario.

Generally speaking, there have been no occurrences of low oxygen concentration in Lake Ontario which have paralleled the situation in eastern Lake Erie. In eastern Lake Erie, however, percentage saturation in the deepest bottom waters has gone from a range of 81 to 89 in 1928 and 1929 to 47 to 81 in 1960--perhaps indicating a deteriorating situation but one still adequate for fish and aquatic life.

There has not been the same degree of study and sampling in Lake Ontario as there has been in Lake Erie. Such work as has been done, however, indicates excellent oxygen conditions, except for local areas in the eastern end, particularly in the Bay of Quinte. Information is still too limited to draw any conclusions from these scattered temporary occurrences of low dissolved oxygen. It has been speculated that local pollution concentrations in the Bay of Quinte may be involved. On the basis of current information, however, it may be stated that dissolved oxygen concentrations in Lake Ontario are optimal throughout most of the lake at all times. Except for the scattered occurrences noted above, which may be explainable as highly localized conditions, there is no evidence of gradual overall worsening of dissolved oxygen levels in Lake

Ontario. Likewise, sampling of bottom organisms in the lake reveals uniformly good populations of pollution intolerant forms such as amphipods, mayfly nymphs, and caddis fly larvae.

Although fish populations have fluctuated widely, as reflected in past records of commercial harvest (Table 6), there is little correlation evident between these fluctuations and environmental changes. This is not to say that such correlations may not exist, but simply that the paucity of data does not permit such relationships to be demonstrated. In both Lakes Michigan and Erie, the gradual enrichment of both environments for a time was responsible for upsurges of fisheries productivity, followed by decline. There is no evidence that such a response has ever taken place in Lake Ontario fish populations.

Two possible explanations have been advanced to account for the lack of oxygen depletion problems in Lake Ontario, in contrast to the widespread manifestation of this phenomenon in Lake Erie, which supplies the bulk of Lake Ontario water. One is the greater average depth of Lake Ontario. This results in a much greater volume of hypolimnetic water below the thermocline when the lake stratifies. BOD, created by fallout from intense algal activity in the surface layer or triggered by complex interactions involving the chemical oxygen demand (COD) of the bottom sediments, may simply lack the magnitude to make any appreciable inroads on the vast store of well-oxygenated hypolimnetic water. Secondly, the relative freedom of inflowing Lake Erie waters from suspended solids and organic matter may tend to inhibit the buildup of latent COD in the bottom sediments of Lake Ontario. In other words, the combination of a relatively clean body of water overlying an essentially fouled bottom--the situation that characterizes Lake Erie--does not appear to be duplicated in Lake Ontario.

The long-range prospects for improvement in the water quality situation in localized inland and inshore areas in the United States portion of the basin are good with respect to organic and inorganic compounds directly or indirectly injurious to fish or their utilization. Current and proposed plans to attack the problem directly through improvement of waste treatment facilities and related technological innovations are receiving high priority attention. New York passed a one-billion dollar bond act in 1965 to help fund the water pollution abatement program. New York State's proposed water quality standards have been approved by the Secretary of the Interior under the provisions of the Water Quality Act of 1965 (Public Law 89-234) except for temperature and mixing zone parameters which are still under consideration. In this respect, these stands must be considered interim in nature. A great deal has yet to be learned about adequate aquatic life criteria. Additional research may demonstrate the need for redefinition and refinement of the standards to meet fish and wildlife requirements.

Existing water quality over most of the open waters of Lake Ontario exceeds the standards, for most if not all parameters. Until careful research demonstrates beyond a reasonable doubt that degradation of existing water quality to the level of the standards will not result in harmful effects upon fish and aquatic life resources, it is the position of the Bureaus of Commercial Fisheries and Sport Fisheries and Wildlife that the existing high quality of the open waters of Lake Ontario should be maintained or enhanced.

It is not within the scope or competence of this report to give a detailed review of water quality conditions in the Canadian portion of Lake Ontario. In general, it is believed that deterioration has taken place in the inshore waters and in local areas such as the Bay of Quinte to a degree roughly equal to that prevailing in United States inshore waters. From the fisheries standpoint, this localized deterioration of water quality in Canada may have a greater effect than its United States equivalent. This is because the Canadian waters contain a disproportionate amount of the spawning areas for some of the more important fish species. Canadian authorities are aware of their water quality problem and steps to implement remedial measures are under way.

Implementation of the pollution abatement plan as presented in this Federal Water Pollution Control Administration report will result in betterment of water quality conditions from the fisheries standpoint. The most direct and immediate benefits will be felt in the inland lakes, tributaries, and inshore waters of the basin. In the open lake, lack of knowledge of the interaction of the complex factors involved makes definitive analysis difficult. Even here, however, the Federal Water Pollution Control Administration's plan can contribute to avoiding a duplication of the Lake Erie experience. To get the maximum remedial results in this area, accelerated research to determine water criteria for fish and aquatic life and to get a better understanding of the causative mechanisms of environmental change will be as important as waste treatment works. This is particularly true in the case of Lake Ontario, since less is known of the fish populations and their environment here than in any of the other Great Lakes. Some of the research requirements are spelled out in greater detail in the previous section on management-oriented requirements. An attempt has been made to meet these research requirements by the Bureau of Commercial Fisheries, New York State, and Canadian fish and wildlife agencies as well as university research staffs, to the extent that funding has allowed. Unfortunately, in many areas, this has been largely a token effort.

ENVIRONMENTAL RESEARCH REQUIREMENTS

General

In order to obtain maximum benefits from an environmental research program and to assure continuity in data collection, there must be adequate coordination and exchange of information. Because fishery agencies have a broad responsibility to maintain harvestable surpluses in existing populations of aquatic life and to contribute to man's understanding and control of aquatic living resources and their environment, it seems logical that these agencies should also have a major role in coordinating and conducting research related to long-term water quality changes. Without proposing any specific institutional arrangements, this function may be exercised through such established mechanisms as the Great Lakes Fishery Commission, where an ecosystem approach encompassing all of the Great Lakes can be adopted.

Monitoring Environmental Conditions

Continuous measurement and evaluation of basic environmental features are needed to provide the background of information required to interpret and predict fluctuations and trends in fish distribution and abundance. The limited amount of such work done in the past on Lake Ontario underscores the need for acceleration. Such studies should extend to the tributaries of Lake Ontario, to sources of domestic and industrial pollution, and to those physical and chemical processes within the lakes which concentrate, add, or remove material. Information from current research relevant to fishery problems should be obtained and evaluated to permit the correlation of fish population dynamics with the increased knowledge of environmental change. Presently, sampling and investigatory data are inadequate to do this in a meaningful way in Lake Ontario.

As experience revealed the development of stable patterns for certain environmental features, (e.g., certain dissolved solids), work on them could be reduced while the level of monitoring effort on features of critical concern (e.g., heavy metals and pesticides) could be increased. Another area for concentration would be interrelationships between tributary and inshore environments and fish populations in the open lake. This is closely related to environmental effects on fish populations of engineering projects involving dredging and dumping in these same habitats--another critical area on which little firm information is available. Monitoring efforts would pay particular attention to the effects of atomic reactors and large power plants.

Bottom Sediments

Bottom organisms are consumed by almost all fish at some stage of their lives, and the scarcity of certain species may significantly affect fish growth and survival. Bottom organisms are also useful indicators of subtle physio-chemical changes in water quality. The important, and perhaps predominating, role of the bottom sediments in long-range water quality changes of the Lake Erie ecosystem has already been mentioned. It does not appear that a similar problem exists in the bottom sediments of Lake Ontario. There has, however, been virtually no work on these sediments and this is a most pressing requirement. If initial sampling indicates that a problem may exist, more detailed investigations would be in order.

Plankton Productivity

Plankton organisms are the most important primary converters of basic energy and nutrients in the open water areas of the Great Lakes. The amounts and rates of nutrient fixation are the most influential factors in controlling the levels of abundance and potential yield of fish stocks. Thus, the mechanics and role of this system must be measured and understood to provide information needed to predict fluctuations and levels of fish abundance, and to discover means of stabilizing productivity and achieving higher levels of sustained yield.

The initial phase of this investigation should be the development of more reliable quantitative sampling gear. Much of the equipment for measuring light, temperature, and for determining the concentrations of major nutrients is presently available, although modifications, both of equipment and methods, may be necessary for problems peculiar to this study. The work should be coordinated closely with studies on biology of fishes and monitoring the environment.

ECONOMIC

General

The analyses of the historical and current commercial fishery situation in the Lake Ontario Basin show it sharing the basic economic problems of the total Great Lakes fishery. These consist fundamentally of too many small, uneconomic producing units, many of which have now collapsed; outmoded equipment, limited capital for investment in modernization; and a desultory market demand for many of the traditional products. In addition, all the Great Lakes commercial fisheries have suffered from reduction in stocks of higher-priced species with corresponding increases--often dramatic increases--in supplies of low-priced fish with a sluggish market. While solution to all these economics-related problems will be required more or less in concert, the problem of market demand is a particularly fundamental one.

Information is lacking on consumer preferences and other forms of market research which would aid in stimulating and enlarging demand. Economic studies are needed which would relate biological information on the level, composition and stability of the supply to the costs and efficiency of various fishing and processing methods and to the demand. Investment-profit relationships will show if unused or underutilized stocks can be produced at a profit, or point out areas where technological research is needed to provide the efficiency or market demands that will permit a profit. The value of balanced exploitation in improving the recreational as well as the commercial fisheries must not be overlooked in striving for greatest economic benefits in utilizing the fishery resources of the Great Lakes.

The first requirement, therefore, is one of adequate economic studies of both the sport and commercial fisheries. These studies should be of sufficient depth and scope to get answers that will enable rational decisions to be made in overall development of the resources. These program requirements are discussed in greater detail under the following headings.

Marketing Program

Historically, marketing of the United States Great Lakes fishery products at the fisherman level has consisted principally of sales in the round, or with only a minimum of processing. For the traditional high-valued species this method was probably adequate. However, it appears now that a more integrated harvesting-processing-marketing arrangement is necessary in order to compete with other fishery and animal products. The organization of such enterprises will require coordinated efforts of the industry itself, with the encouragement and assistance of State and Federal agencies. This active governmental assistance is a key ingredient. It probably accounts for much of the recent growth in Canada's Lake Ontario commercial fishery, while the United States catch and earnings have been declining. There are two areas of the marketing program which require specific attention.

1. Marketing research. Detailed information is not available on the market areas and consumer segments for those species abundant in Lake Ontario. Data should be developed to meet these needs, including the identification of species distribution and preferences among geographic areas and ethnic and income groups.

2. Market development. This involves both intensification of consumer education through mass-information media, selective emphasis on specific consumer groups and aggressive development of new outlets for Lake Ontario fishes, especially the lower-priced species. There has been some recent expansion of such marketing outlets in the fields of animal food, fishmeals, and fish oils in the Great Lakes area, primarily on Lake Michigan. The economic feasibility of large scale production of fishmeal and fish oil from freshwater species has also been established. In addition, a firm on Lake Superior has been successful in test marketing attractively packaged, frozen fish (herring and chubs) produced by relatively modern processing methods.

Processing Technology Program

No dramatic reversal in the availability of traditional "fine-food" species from Lake Ontario can be anticipated while an increasing relative availability of current low-value species may be expected. It is, however, quite possible to upgrade the relative worth of this abundant resource for human food, but this will require relatively large catches of fish handled promptly and economically through the harvesting, handling, and processing chain.

1. Improvement of products. The greatest need for industry in the area of products for human consumption is a departure from traditional product forms (i.e., the fresh, dressed fish philosophy) to concepts related to modern merchandising practices. Such would include frozen, boneless, skinless convenience items

suitable for portion-control type feeding programs (e.g., Individually Quick Frozen (IQF) fillets, portions, cakes, etc., breaded or non-breaded). Of even more consequence would be a breakthrough in production of a uniform, boneless, skinless raw material intermediate of a non-powdered type that could serve for a variety of final or "finishing" product interests. Species identity of the original input would tend to receive less emphasis in this type of production, with obvious gains for increased utilization of such common Lake Ontario species as carp. Currently, mere use of the name invokes automatic consumer resistance.

Technologists are currently developing techniques to control, for example, rancidity development and undesirable color changes in such species as white bass, smelt, and sheepshead. New product forms, such as IQF fillets, blocks, and processed portions are being considered as well as related packaging needs. New research is planned on the previously cited potential of a fishery raw material intermediate for carp, sheepshead, and other problem species. Studies are in progress to determine the applicability of using pasteurization levels of gamma radiation to extend the refrigerated shelf life of various Great Lakes species, in order to expand the fresh market area for products such as fillets.[33/] [34/] [35/] [36/] With the anticipated approval of this process for fish by the Food and Drug Administration, it is expected that marketing channels in the central portion of the United States will begin to handle such products.

To increase future industrial consumption, it will be necessary to concentrate upon:

1. Improved processing. Attain a high level of mechanization in the harvesting and handling of the raw fish,[37] and establish manufacturing outlets capable of rendering such raw materials to high-quality, uniform, nutritious, safe products for animal consumption. Some degree of processing of the raw fish is necessary,[38] such as through a fish meal or similar type operation. Technologists have been developing such a rendering process which might well be applicable to the needs of the Lake Ontario industry. This process renders much of the moisture and oil (containing a large portion of the pesticide residues of the fish) from the raw fish. It also renders inactive the thiaminase factor (present in many of the Lake Ontario species), and yields a press-cake product tailored for direct supplementation of mink diets, or suitable as a more uniform raw material for use in canned pet food production. The "intermediate" press-cake may also be dried to a fish meal-like product.

2. Defensive technology. This may be defined as the development of methods and techniques to remedy or offset undesirable and hazardous conditions that interfere with the smooth safe flow of commercial fisheries products to market. For example, to avoid further outbreaks of botulism poisonings, related to improperly-processed or handled fishery products, more basic information on the botulinum organisms is necessary, including the extent and manner it is present in the fisheries environment. Considerable

work, which is also applicable to Lake Ontario, has already been done on the botulinum problem in Lake Erie and the Upper Great Lakes. Some supplementary investigations will be required, however, to find out more on the specific variations of the Lake Ontario environment. Likewise, some additional work will be required to apply to Lake Ontario the extensive microbiological knowledge already gathered on the commensal spoilage flora associated with Lake Erie fish.

Better knowledge of the chemical composition and related process-induced changes occurring in fresh-water fish is being obtained. This will assist in controlling adverse flavor, odor, and color changes in processed products. Some of these changes are apparently closely related to the chemical make-up of the fishery material, which in turn is affected by the nature of the fishery environment and its relative state of degradation by pollution and other factors.

Mandatory inspection and better quality control of fishery products in the United States is on the way but effective implementation will require better knowledge and more refined techniques.

Exploratory Fishing and Gear Research Program

The general goal of the Bureau of Commercial Fisheries exploratory fishing and gear research program is to find the most economical means to catch each commercial species in each body of water. Species selectivity will receive heavy emphasis. It will be necessary to study factors which influence fishing effectiveness, fish distribution, seasonal availability, effects on protected species, and feasibility of various fishing systems. The ultimate objective is to help develop a modern commercial fishery which will be able to easily adjust to changing conditions, management requirements, and socio-economic considerations.

As a base upon which Lake Ontario fisheries can be developed in the future, it is necessary to know when, where, and how much of the important commercial species can be harvested from year to year. It is also necessary to know what fishing systems are required and what the production rates and production costs will be. Periodic systematic exploratory fishing surveys furnish much of this information, but other research and development activities are equally important. These activities are aimed at improving all aspects of fishing vessel design and at discovering better means of locating, selectively capturing, and handling fish.

Summary of Economics-Oriented Requirements

The basic problem consists of modernizing an outdated and under-capitalized industry. It must be responsive to new consumer requirements and needs, while facing the challenges of a resource environment and species composition that are changing. These alterations are due to many factors, including the effects of water quality changes and pollution. Greater research promotional activity, quality control, and increased international, Federal, State and local cooperation are all needed, plus more participation by industry, universities, and other segments of the private sector. In addition to these necessary but rather generalized requirements, a more immediate type of catalyst is needed to solve the basic problem with reasonable rapidity. Two possibilities are suggested:

1. Establishment of a fish meal plant. This need not necessarily be located within the Lake Ontario Basin. It is quite possible that a location within the Lake Erie Basin might satisfactorily service both areas by offering an outlet for presently unutilized stocks of low-value fish. Development and financing of this facility should be largely the responsibility of the private sector, but the need is great enough to warrant some degree of appropriate governmental aid.

2. Establishment of a pilot commercial fish processing plant. Again this would not necessarily be located within the Lake Ontario Basin. A location capable of servicing both the Lake Erie and Lake Ontario Basins might be more desirable. The purpose of such a pilot plant would be to bridge the gap between the promising experimental innovations for utilizing abundant stocks of low-value fish and implementation of self-sustaining commercial operations--again with such government aid as may be appropriate.

SUMMARY

On the basis of a framework-type analysis appropriate for this report, the following conclusions are drawn concerning the present and future status of the Lake Ontario fishery in relation to water quality:

1. Over the period of record the Lake Ontario commercial fishery (United States and Canada combined) has always had the lowest production of any of the Great Lakes.

2. Stocks of the higher value species such as lake trout, whitefish, lake herring, blue pike, white perch, and walleye have declined, in some cases to the point of commercial, if not biological, extinction. The United States fishery now depends heavily on carp, yellow perch, white perch, bullheads, and eels. Stocks of alewife and smelt are moderately abundant, with the latter being utilized extensively in the Canadian but not the United States fishery.

3. Less is known of the Lake Ontario fishery and its environment than that of any of the other Great Lakes. Consequently, analysis and explanation of its fish population dynamics is correspondingly difficult. Clear-cut turning points, such as the sea lamprey invasion and introduction of the alewife which serve as convenient bench marks for tracing major changes in the fishery dynamics of the other Great Lakes, are generally not applicable in Lake Ontario. The sea lamprey has always been present in Lake Ontario, while the alewife has been present in the lake, at least since 1890.

4. There have been three introductions to the Lake Ontario species complex. These are the carp (before the turn of the century; the smelt (1930's); and the white perch (1950's). There is some speculation that proliferation of the introduced smelt may be correlated with the decline of the blue pike, but not enough is known to reach a definitive conclusion.

5. Spawning areas for lake trout and whitefish are concentrated in the eastern end of the lake, primarily in Canadian waters. This lack of diversified spawning sites is in contrast to the situation prevailing in the Upper Lakes and has made the fish stocks particularly vulnerable to seasonal over-fishing. This vulnerability is increased by the tenuous nature of the balance that historically prevailed between the sea lamprey and its prey species. This concentration of limited spawning areas may also be a factor in the case of other species.

6. Re-establishment of a balanced predator-prey relationship in Lake Ontario is essential to achieving a stable and productive resource base. It is generally agreed that sea lamprey control will have to be initiated eventually in Lake Ontario, despite the special problems involved. Introduction of salmonid predators is already under way in both New York and Ontario. Careful monitoring of the fishery base will be necessary as these activities proceed, in order to determine the nature of the changes that occur and to indicate any possible adjustments which may be necessary in management procedures.

7. The overall low productivity of the total fishing resource in Lake Ontario is difficult to account for on the basis of knowledge currently available. Much more research and study will be required.

8. The combined United States-Canadian commercial fishery in Lake Ontario has demonstrated overall decline, with this decline particularly apparent to the United States segment. Greatest annual catches were taken prior to the turn of the century, followed by stabilization between three and four million pounds until the mid-forties. Subsequently, there has been a further decline, dipping below two million pounds in recent years.

9. Initially, United States and Canadian production was roughly equal. Presently, only 10 percent of the total harvest is taken by the United States fishermen and more than half of this comes from Chaumont Bay. Numbers of United States fishermen have dropped from over a hundred regular fishermen in the 1930's to a current level of one full-time and two part-time fishermen in the lake proper, plus 10 part-time fishermen in Chaumont Bay.

10. A number of factors have contributed to the present condition of the industry. Decline in abundance of the more valuable species (lake trout, whitefish, lake herring, and walleye) was of major importance. Fluctuations in the resource base have increased the uncertainty associated with commercial fishing in the United States, thereby limiting the desirability of investment in the fishery. Limited demand for the lower-valued species

currently available has been a further depressant. Increased cost of labor and materials further depresses expansion of the commercial fishery.

The inability or unwillingness of the United States fishermen to alter traditional methods of processing and marketing has led to a loss of competitiveness in the changing fishery products market. Restrictive and outmoded regulations have also played a part.

11. The Canadian fishery is better located with respect to the most productive fishing grounds, has operated under what is essentially a limited entry situation, has made more use of modern harvesting methods, and in general has developed a higher level of processing and marketing technology.

12. Many of the problems of the Lake Ontario commercial fishery are common to the overall Great Lakes fishery. Solutions to the problems are likely to be related to overall progress and development throughout the Great Lakes. This would include advances in harvesting and processing technology. It should become more responsive to changing consumer demand, market development, and reorganization of the fishery to fit the concept of balanced utilization of the total fishery resource. This includes a mutually supportive role between the sport and commercial fisheries. In this context, development of outlets for the large supplies of low value fish in Lake Erie (e.g., a fish meal plant) might simultaneously enable the Lake Ontario fishery to contribute on a scale commensurate with its lower productivity.

13. Potential demand for commercial fishery products from the Great Lakes is estimated to increase by more than fourfold by the year 2020. Even with the advances in harvesting, processing and marketing indicated in this report and development of data necessary for effective management systems, water quality is likely to become a constraint to meeting future demands.

14. From the commercial fishing standpoint, Lake Ontario is the least productive of the Great Lakes. In the other Great Lakes, commercial fishing productivity can be roughly correlated with the basic fertility of the environment. This correlation is much more difficult to demonstrate in Lake Ontario.

15. Except in the vicinity of major urban concentrations, Lake Ontario's inshore waters do not exhibit obvious signs of water quality degradation. However, the rapid proliferation of Cladophora since the 1950's is evidence of accelerated enrichment of these inshore waters. Oil pollution, originating from vessels is a serious problem.

16. Water quality is still high in the open waters of Lake Ontario, although there has been change. Concentrations of total dissolved solids have increased at an accelerated rate since 1910, paralleling the increases that have taken place in Lake Erie. Lake Ontario concentrations are slightly higher than Lake Erie, due to the addition of inputs from its own basin to the waters it receives from Lake Erie.

17. Despite higher concentrations of various dissolved solids than occur in Lake Erie, the open water of Lake Ontario has not developed comparable worsening of environmental conditions. Concentrations of dissolved oxygen are generally high, except for a few localities in the eastern end of the lake. Benthic fauna flourishes throughout the lake. The morphometry of Lake Ontario and its comparatively low road of suspended solids probably contribute to the failure to develop adverse conditions comparable to Lake Erie.

18. Preliminary investigations indicate that concentrations of pesticides such as DDT and dieldrin in fish do not follow the Lake Erie pattern. These substances are present in almost negligible concentrations in Lake Erie fish, whereas Lake Ontario concentrations are roughly equivalent to those of Lake Huron. This indicates buildup from within the Lake Ontario Basin itself to levels only one-half to one-third lower than measured in Lake Michigan fish. From the fisheries standpoint, this aspect of water quality demands the most immediate remedial action.

19. Although water quality changes to date throughout the Lake Ontario ecosystem have not proceeded to a point resulting in demonstrable adverse effects in fish and wildlife resources, the changes that have taken place should be viewed seriously. They are indicators that steps should be taken without delay to slow down, and eventually halt, inputs of pollution. The pollution control plan, as outlined in this Federal Water Pollution Control Administration report, should be implemented as a necessary first step.

20. As a result of the 1965 Water Quality Act, New York has improved their water quality standards. Under provisions of the Act, the Secretary of the Interior has approved all but the temperature and mixing zones standards proposed by New York. In this important respect these standards must be considered interim in nature. A great deal has yet to be learned about adequate aquatic life criteria and additional research may demonstrate the need for redefinition and refinement of the standards to meet fish and wildlife requirements. In the meantime, it is apparent that existing water quality over most of Lake Ontario's open waters exceeds the standards, for most if not all parameters. Until careful research demonstrates beyond a reasonable doubt that degradation of existing water quality to the level of the standards will not result in harmful effects upon fish and aquatic life resources, it is the position of the Bureaus of Commercial Fisheries and Sport Fisheries and Wildlife that the goal of pollution abatement in Lake Ontario should be retention or enhancement of the existing overall high quality of its waters.

21. Because of the special relationship of fish, wildlife, and aquatic organisms to long-term changes in water quality and the responsibility of State and Federal fishery agencies to increasing man's control of aquatic living resources and their environment, research on long-range environmental changes should be conducted by these agencies and coordinated through established institutions such as the Great Lakes Fishery Commission, with the help and cooperation of private and educational groups.

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